A REPORT ON THE ENVIRONMENTAL ARCHAEOLOGICAL ANALYSIS OF BOREHOLES COLLECTED FROM THE LONDON CABLE CAR ROUTE, LONDON BOROUGHS OF NEWHAM AND GREENWICH (site code: CAB11)

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INTRODUCTION

This report summarises the findings arising out of the environmental archaeological analysis undertaken by Quaternary Scientific (University of Reading) in connection with the proposed Cable Car development in the London Boroughs of Newham and Greenwich (National Grid Reference: spanning TQ 40111 80696 (north) to 39478 79745 (south); site code: CAB11). The site spans Bugsby's Reach of the tidal River Thames between the North Greenwich 'peninsula' (meander core) on the right (south) bank and the Royal Victoria Dock on the left (north) bank. The site itself is divided into five main areas in which geotechnical investigations (test pits, window samples, cable percussion boreholes and rotary boreholes) were recently carried out by Soil Mechanics on behalf of Mott MacDonald, as follows: (1) the North Station (NS); (2) the North Intermediate Tower (NIT); (3) the North Tower (NT); (4) the South Tower (ST), and (5) the South Station (SS) (Figure 2). In addition two overwater boreholes were put down as part of a future potential tunnel project within the course of the River Thames (TU).

These geotechnical works were monitored by Quaternary Scientific and integrated with existing records as part of a geoarchaeological investigation carried out to create a model of the depositional history of the site (Green *et al*., 2011; Figures 3 to 5; Tables 1 & 2; Appendices 1 & 2). The resultant model included 36 borehole records and revealed London Clay bedrock (Unit 1) overlain by the Shepperton Gravel. The gravel surface formed a relatively level surface on the south bank of the Thames (-2.25m to -3.45m OD), but was deeper and more undulating to the north (between -2.50m and -5.88m OD), and with one borehole indicating a much higher surface of +1.55m OD. Resting on the Shepperton Gravel was an alternating sequence of Alluvium (Units 3a and 3b) and Peat (Unit 4); in some cases, multiple units of Peat were recorded. Each sequence was truncated to various depths by a Made Ground, sometimes >10m thick and cutting into the Shepperton Gravel.

The geoarchaeological investigation also highlighted sequences at the North Tower (<NTBH03>) and South Station (<SSBH1C>) that contained thick sequences of Peat and

Alluvium with potential to reconstruct the environmental history of the site and its environs, and for identifying evidence of human activity (Figures 2, 3 and 6). These borehole core samples therefore underwent an environmental archaeological assessment (Batchelor *et al*., 2011). The results of this assessment indicate that deposition commenced around 10,500 cal yr BP and continued until at least *ca*. 3000 cal yr BP in <NTBH03>, equating to deposition during the Mesolithic, Neolithic and Bronze Age cultural periods. The results of the archaeobotanical assessment (pollen, waterlogged wood and waterlogged seeds) indicate that during the deposition of the basal Peat, the local environment was first dominated by grasses and sedges with pine and birch woodland, prior to a transition towards alder dominated fen. The alder dominated fen remained dominant through the main Peat horizon. On the dryland, mixed oak-lime woodland dominated throughout the majority of the sequence. The results of the diatom assessment show that frustules were present (generally in low concentrations) in certain samples, and these have the potential to reconstruct the hydrological history of the site. Insects and Mollusca were noted in limited concentrations during the bulk sample assessment.

The chronology and provisional vegetation history indicated by the <NTBH03> sequence was identified as being similar to that made at the nearby West Silvertown site located approximately 500m to the east (Figure 1; Wilkinson *et al*., 2000). One of the key exceptions to this is that the Holocene sedimentary sequence at <NTBH03> commences approximately 3m deeper and 2000 years later than that at West Silvertown. In addition, *Ulmus* (elm) and *Taxus* (yew) represent an important component of the West Silvertown pollen sequence but are not recorded at the new site. The decline of elm, and colonisation and decline of yew represent significant vegetation changes during the Neolithic cultural period that are recorded at a number of sites along the course of the Lower Thames Valley, but particularly on the north bank of the river and in the Newham area (Batchelor, 2009; Gifford and Partners, 2001; Scaife, 2001; Wilkinson *et al*., 2000; Jarrett, 1996; Divers, 1995; Tamblyn, 1994). The absence/limited concentration of pollen recorded at the new site is therefore significant to the mapping of ancient woodland along the course of the Thames. Furthermore, the cultural periods represented in the <NTBH03> correlate with archaeological discoveries made in the nearby vicinity including: (1) a prehistoric structure (possible trackway) at Fort Street, Silvertown (Wessex Archaeology, 2000; Figure 1), and (2) Mesolithic and Bronze Age flints, pottery and debris at the Royal Docks Community School (Holder, 1998; Figure 1). Therefore, whilst no anthropogenic indicators were recorded during the assessment stage, the proximity of these sites, suggests there is potential to trace human activity during the environmental archaeological analysis stage.

In South Station borehole <SSBH1C>, deposition occurred between at least *ca*. 5500 and 3500 cal yr BP equating to the Neolithic and Bronze Age cultural periods. The results of the archaeobotanical assessment (pollen, waterlogged wood and waterlogged seeds) indicate that the local wetland environment comprised alder dominated fen, with a transition towards wetter, more open conditions towards the top of the Peat. On the dryland, the surface was occupied by mixed oak-lime dominated woodland, which also declined towards the top of the sequence, and more open conditions indicated. The results of the diatom assessment show that frustules were present (generally in low concentrations) in certain samples, and these have the potential to reconstruct the hydrological history of the site. Insects were noted in limited concentrations during the bulk sample assessment.

Elm pollen was recorded more frequently in the <SSBH1C> sequence, and a tentative identification of yew pollen was made at -2.14 to -2.15m OD. No strong *Taxus* pollen signal has been recorded within this area of the Thames (nor have any trees or macrofossil remains). The new record is therefore significant for mapping the former distribution of yew on the floodplain surface in this area of the Lower Thames Valley. Furthermore, there are few environmental archaeological records from this area, and thus analysis on the <SSBH1C> sequence would add to our knowledge and understanding of the general palaeoenvironmental conditions. Some of the nearest archaeological remains recorded on this side of the river were a Bronze Age wooden trackway(s) within the Peat at two sites on Bellot Street (Branch *et al*., 2005; McLean, 1993; Philp, 1993). However, the potential for finding archaeological remains at the new site within the Peat is probably limited due to the frequent truncation and contamination of sequences noted during the geoarchaeological fieldwork (Green *et al*., 2011).

Following the results of the environmental archaeological assessment, both sequences (<NTBH03> and <SSBH1C>) were recommended for high resolution analysis, incorporating (1) further organic matter determinations; (2) further radiocarbon dating; (3) pollen; (4) diatoms; (5) waterlogged plant macrofossils (seeds and wood) and (6) insects. These investigations will provide a detailed reconstruction of the environmental history of each site, and elucidate evidence for human activity and sea level change. The investigations also provide the opportunity to increase knowledge and understanding of the distribution of ancient woodland across these areas of the Lower Thames Valley. The following report outlines the results of the environmental archaeological analysis.


Bromley
TOWER HAMLETS
Mile End
Bow Common
Limehouse
POPLAR
South Bromley
Blackwall
Canning Town
Plaistow
Beckton
Custom House
Royal Victoria Dock
Exhibition Centre
London City Airport
Albert Dock
King George V Dock
Silvertown
North Woolwich
New Charlton
Charlton
GREENWICH
Millwall
ISLE OF DOGS
Cubitt Town
River Thames
Bugsby's Reach
Woolwich Reach
Blackwall Reach
Limehouse Reach
Greenwich Reach
The Thames Flood Barrier
Thames Barrier Park
Canary Wharf
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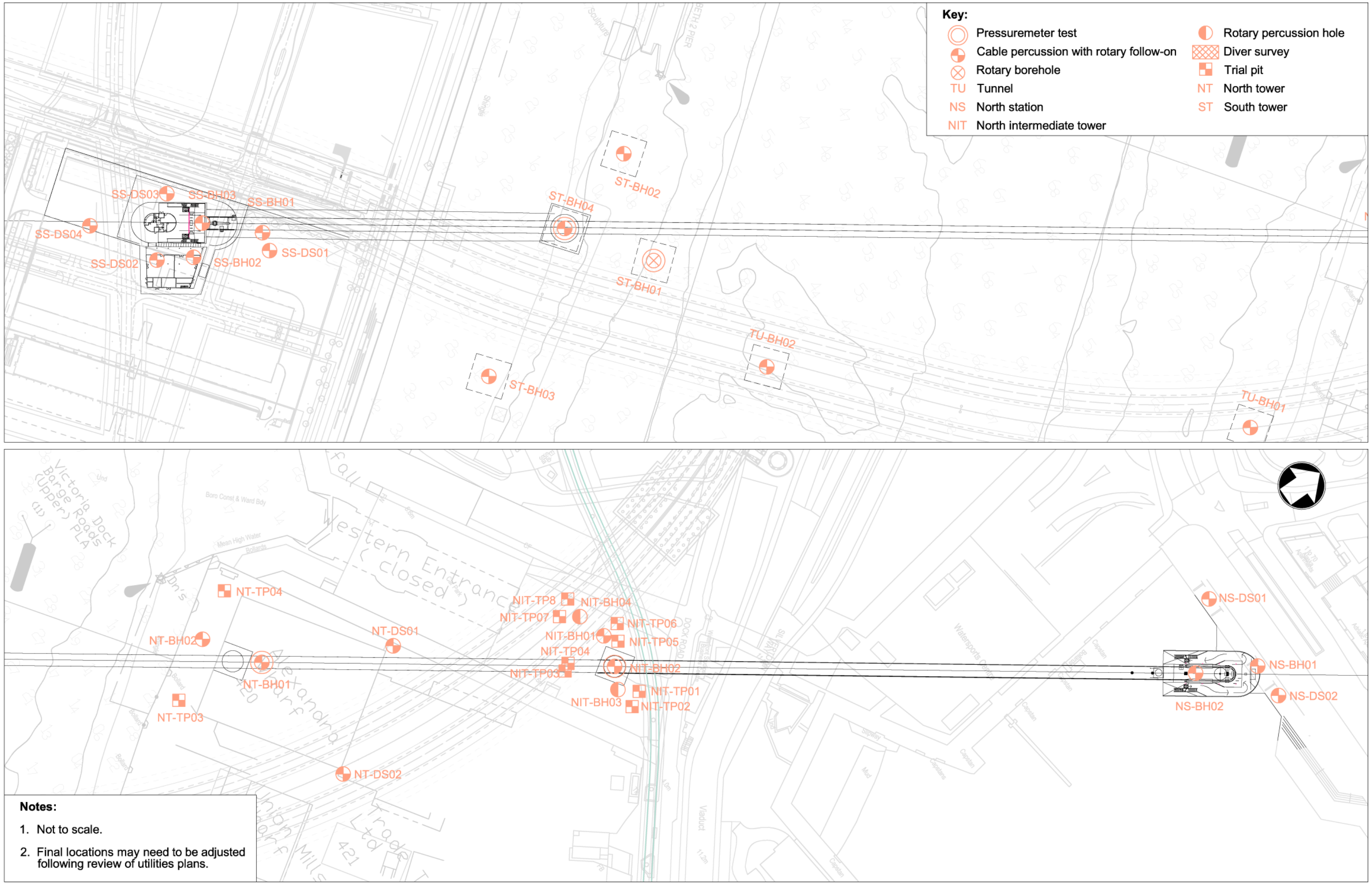
Figure 1: Location of (1) the Cable Car route ((A) North Station; (B) North Intermediate Tower; (C) North Tower; (D) South Tower; (E) South Station), London Boroughs of Newham and Greenwich and other nearby locations: (2) Bryan Road (Tucker, 1993); (3) Atlas Wharf (Lakin, 1998); (4) Preston Road (Branch *et al*., 2007); (5) East India Docks (Pepys, 1665); (6) Bellot Street (Branch *et al*., 2005); (7) 72-88 Bellot Street (McLean, 1993; Philp, 1993); (8) Silvertown (Wilkinson et al., 2000); (9) Fort Street (Wessex Archaeology, 2000); (10) Greenwich Industrial Estate (Morley, 2003); (11) Royal Docks Community School (Holder, 1998); (12) Beckton Nursery (Divers, 1995); (13) Beckton 3D (Meddens, 1996; Truckle, 1996); (14) A13 Woolwich Manor Way (Gifford and Partners, 2001); (15) Beckton Alp (Truckle and Sabel, 1994); (16) Golfers' Driving Range (Batchelor, 2009; Carew *et al*., 2009); (17) Beckton Tollgate (Tamblyn, 1994); (18) East Beckton District Centre (Jarrett, 1996); (19) East Ham FC (Scaife, 2001); (20) Albert Dock (Spurrell, 1889); (21) Royal Albert Dock (Batchelor, 2009); (22) Albert Road (Spurr *et al*., 2001); (23) North Woolwich Pumping Station (Sidell, 2003)



London Cable Car
Exploratory Hole Location Plan

Mott MacDonald

Figure 2: Detailed plan of the Cable Car route, London Boroughs of Newham and Greenwich (site code: CAB11).

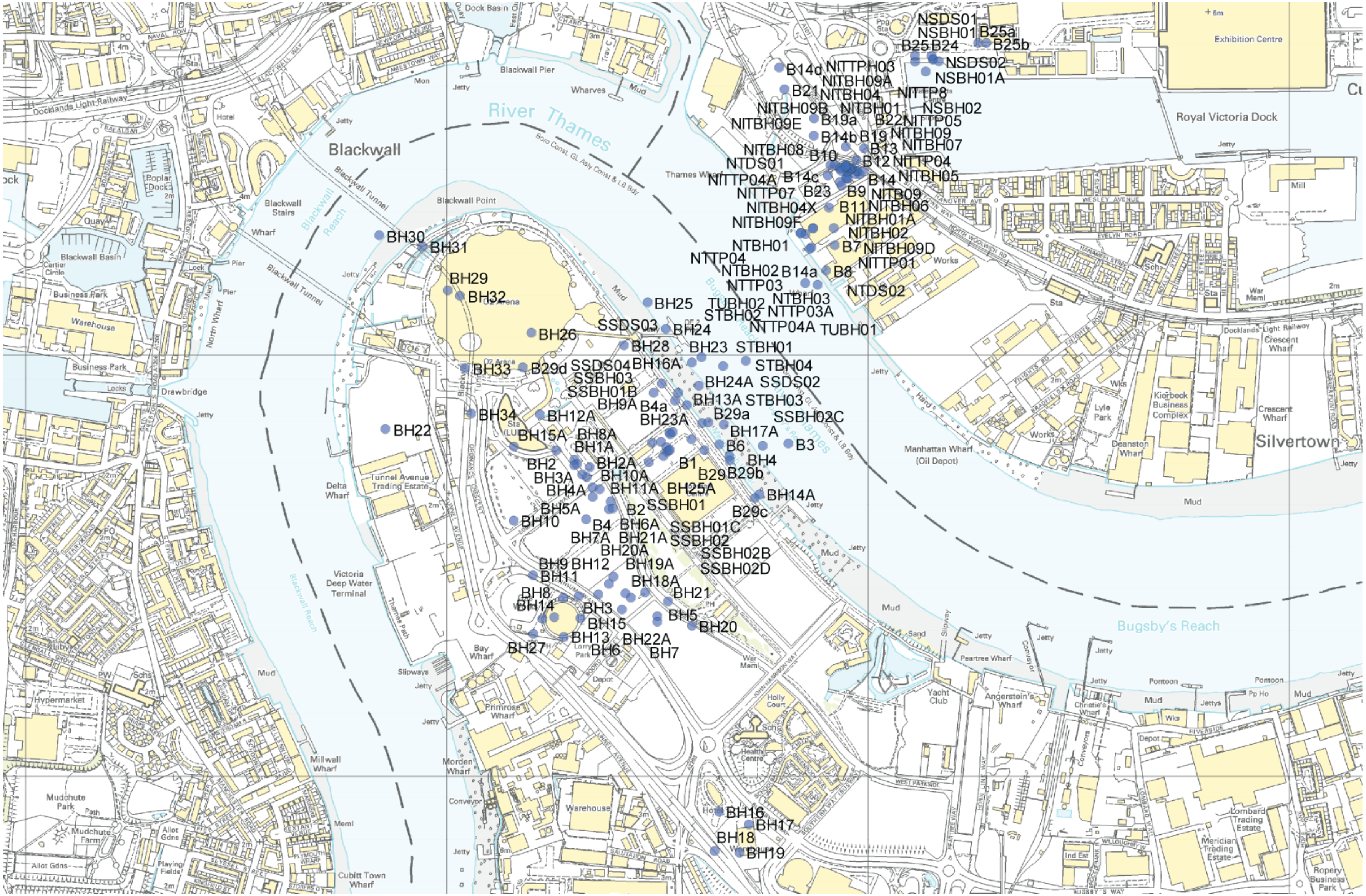


Figure 3: All geotechnical and BGS borehole locations from the Cable Car route and surrounding areas

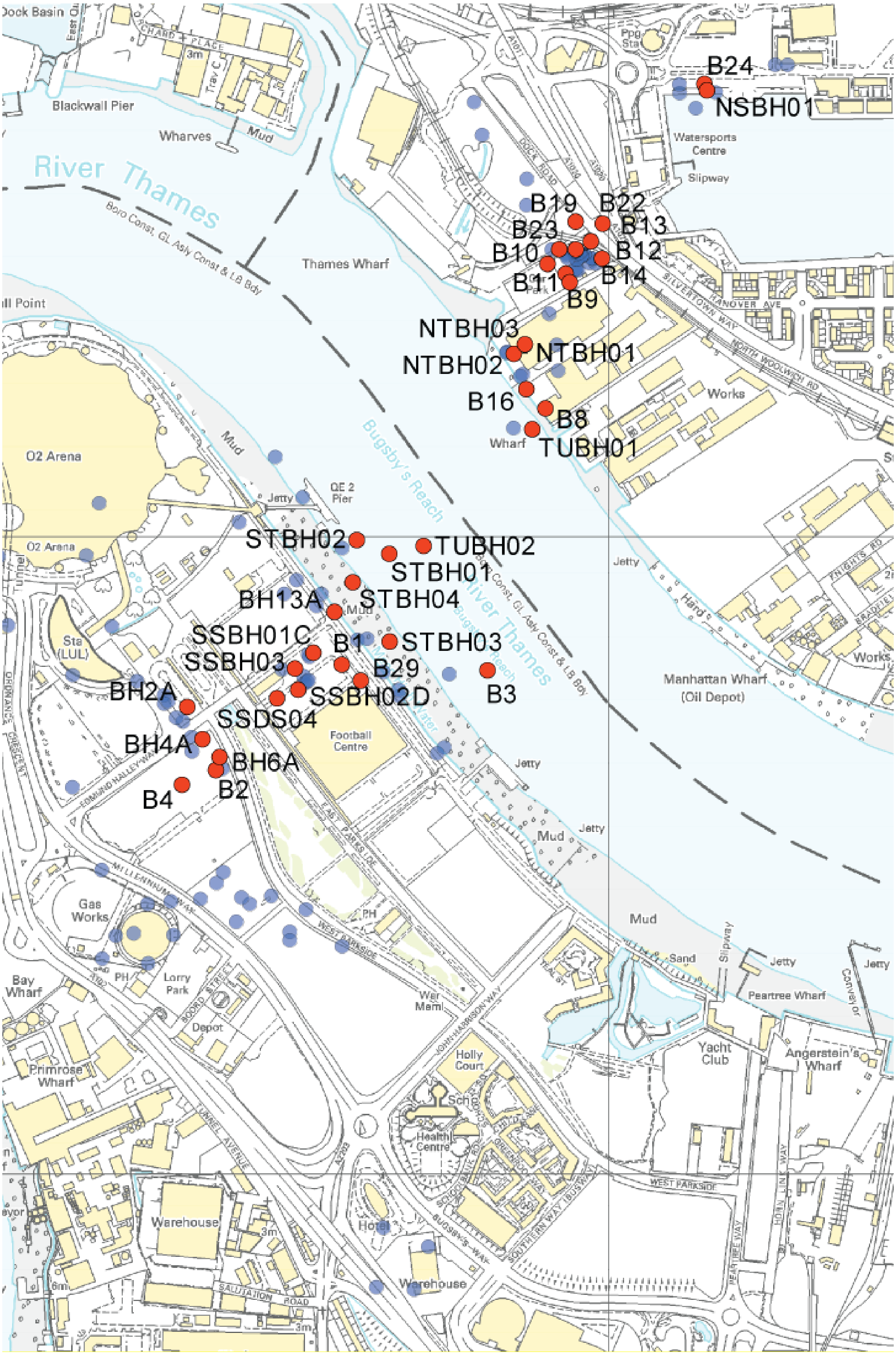


Figure 4: Transect map of selected boreholes along the Cable Car route, London Boroughs of Newham and Greenwich (site code: CAB11; see Figure 5)

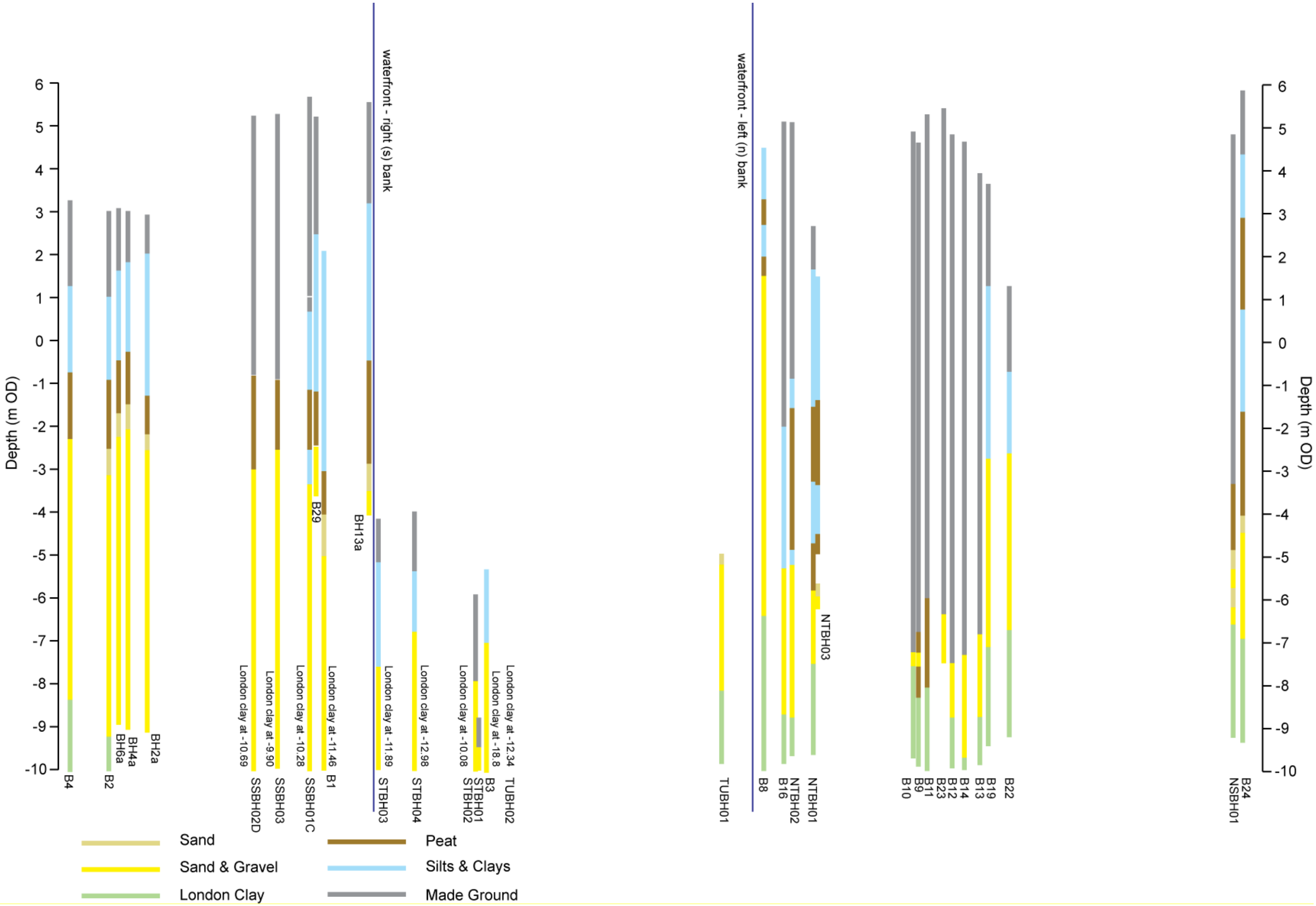


Figure 5: Transect of selected sedimentary logs across the Cable Car route

METHODS

Field investigations

Geotechnical borehole monitoring

Sub-surface investigations of the North Station (NS), North Intermediate Tower (NIT), North Tower, South Tower (ST), and South Station (SS) areas of the site by Soil Mechanics between February and April 2011 provided the opportunity to monitor and record the sediments from fifty-six geotechnical boreholes and test-pits (Figure 2, Appendix 1) which were obtained to various specified depths below surface. Quaternary Scientific visited the site to monitor and record the Holocene deposits from select geotechnical boreholes only (NSBH01, NITBH02, NTBH01, SSBH03). The remaining boreholes/test-pits were not recorded as they were either too closely located to other monitored geotechnical boreholes or were unlikely to penetrate deep enough to reach the Holocene alluvium. However, the geotechnical logs were retrieved for subsequent use in the deposit modelling process.

Each of the selected boreholes was recorded in the field using standard procedures for recording unconsolidated sediment and peat, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter), peat humification and inclusions (e.g. artefacts) (Troels-Smith, 1955). The procedure involved: (1) recording the physical properties, most notably colour using a Munsell Soil Colour Chart, but occasionally dryness; (2) recording the composition, including moss peat (Turfa bryophytica; Tb), wood peat (Turfa lignosa; Tl), herbaceous peat (Turfa herbacea; Th), completely disintegrated organic matter (Substantia humosa; Sh), gravel (Grana glareosa; Gg), fine sand (Grana arenosa; Ga), silt (Argilla granosa; Ag) and clay (Argilla steatoides); (3) recording the degree of peat humification, and (4) recording the boundary changes e.g. sharp or diffuse. The results of the field based descriptions are provided in Appendix 2.

Geoarchaeological borehole retrieval

Following completion of the geotechnical borehole monitoring, two boreholes from the north and south bank of the River Thames were selected for further laboratory-based palaeoenvironmental investigations adjacent to boreholes NTBH01 and SSBH03 (<NTBH03> and <SSBH1C>). These boreholes were specifically chosen as they contained significant thicknesses of Holocene alluvium and peat. This transect provides the potential to identify evidence of change or continuity through time and to establish whether any significant spatial variability exists on either side of the River in this area of the floodplain. U100 core samples were retrieved by Soil Mechanics Limited with a cable percussion rig. At each location, the boreholes extended down to the Gravel. All samples were wrapped and labelled with the depth and orientation, and returned to the University of Reading for cold storage.

Deposit modelling

In the preparation of the deposit model, 153 borehole and test pit logs were examined from an area centred on NGR TQ 3975 8010. Logs were obtained from British Geological Survey archives (97) and from various drilling campaigns specifically associated with the investigation of the Cable Car site (56), including the two palaeoenvironmental boreholes (<NTBH03> and <SSBH1C>) (see Appendix 1 and Figure 3 for details). To develop the deposit model, 36 borehole logs were selected to form a transect extending from NGR TQ 39860 79560 on the south side of the river to NGR TQ 40170 80720 on the north side of the river (selected boreholes are displayed in Figure 4). Thirteen of the boreholes are located on the south side of the river, including palaeoenvironmental borehole <NTBH03>, 7 within the river channel and 16 on the north side of the river, including palaeoenvironmental borehole <SSBH1C>. The criteria for inclusion in the deposit model were (a) proximity to the transect line; and (b) borehole penetration through the full sequence of surviving Holocene alluvial deposits. In practice all but three of the selected boreholes extend down to the bedrock London Clay.

Despite the care taken in the evaluation and selection of the records incorporated in the deposit model, the reliability of the model is affected by the quality of the stratigraphic records which in turn is affected by the nature of the sediments and/or their post-depositional disturbance during previous stages of development on the site. In particular, it is important to recognise that several separate sets of boreholes are represented, put down at different times, by different companies and recorded using different descriptive terms, and subject to differing technical constraints in terms of recorded detail, including the exact levels of the stratigraphic boundaries. The two palaeoenvironmental boreholes described below represent the most detailed record of the Holocene sediment sequence for which accurate height and lithostratigraphic information are available.

In general in the borehole logs it is possible to recognise consistently up to four Holocene sediment units forming Units 3-5 in the present account:

(Unit 6) Made Ground
(Unit 5) Upper Alluvial Silts & Clays
(Unit 4) Peat
(Unit 3) Lower Alluvial Deposits
(Unit 3b) Silts & Clays
(Unit 3a) Sands
(Unit 2) Sand & Gravel (Shepperton Gravel)

(Unit 1) London Clay

Detailed laboratory-based lithostratigraphic descriptions

The retrieved boreholes were recorded in the laboratory using standard procedures for recording unconsolidated sediment and peat, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter), peat humification and inclusions (e.g. artefacts) (Troels-Smith, 1955). The procedure involved: (1) cleaning the samples with a spatula or scalpel blade and distilled water to remove surface contaminants; (2) recording the physical properties, most notably colour using a Munsell Soil Colour Chart, but occasionally dryness; (3) recording the composition, including moss peat (Turfa bryophytica; Tb), wood peat (Turfa lignosa; Tl), herbaceous peat (Turfa herbacea; Th), completely disintegrated organic matter (Substantia humosa; Sh), gravel (Grana glareosa; Gg), fine sand (Grana arenosa; Ga), silt (Argilla granosa; Ag) and clay (Argilla steatoides); (4) recording the degree of peat humification, and (5) recording the boundary changes e.g. sharp or diffuse. The results of the laboratory-based descriptions are provided in Tables 1 and 2, Figure 6.

Organic matter determinations

One hundred and fifteen sub-samples from borehole <NTBH03> and twenty-eight sub-samples from borehole <SSBH1C> were taken for determination of the organic matter content (Tables 3 and 4; Figure 6*)*. These records were important as they can identify increases in organic matter possibly associated with more terrestrial conditions. The organic matter content was determined by standard procedures involving: (1) drying the sub-sample at 110^{0}C for 12 hours to remove excess moisture; (2) placing the sub-sample in a muffle furnace at 550°C for 2 hours to remove organic matter (thermal oxidation), and (3) re-weighing the sub-sample obtain the 'loss-on-ignition' value (see Bengtsson and Enell, 1986).

Radiocarbon dating

In borehole <NTBH03>, sub-samples of *Alnus* sp. waterlogged wood/catkins were extracted from the top and base of the main peat, and base of the lower peat. In addition, one sub-sample of waterlogged seeds (*Rumex*/*Polygonum* sp.) from the base of the organic-rich sequence. Three sub-samples of wood were extracted from the top, middle (both *Alnus* sp twig) and base (unidentified twig) of the peat in borehole <SSBH1C> for radiocarbon dating. All four samples were submitted for AMS radiocarbon dating to Beta Analytic INC, Radiocarbon Dating Laboratory, Florida, USA. The results have been calibrated using OxCal v4.0.1 Bronk Ramsey (1995, 2001 and 2007) and IntCal04 atmospheric curve (Reimer *et al*., 2004). The results are displayed in Figure 6 and Table 5.

Pollen analysis

Twenty six sub-samples from borehole <NTBH03> and twenty sub-samples from borehole <SSBH1C> were extracted for pollen analysis. The pollen was extracted as follows: (1) sampling a standard volume of sediment (1ml); (2) adding two tablets of the exotic clubmoss *Lycopodium clavatum* to provide a measure of pollen concentration in each sample; (3) deflocculation of the sample in 1% Sodium pyrophosphate; (4) sieving of the sample to remove coarse mineral and organic fractions (>125μ); (5) acetolysis; (6) removal of finer minerogenic fraction using Sodium polytungstate (specific gravity of 2.0g/cm^3); (7) mounting of the sample in glycerol jelly. Each stage of the procedure was preceded and followed by thorough sample cleaning in filtered distilled water. Quality control is maintained by periodic checking of residues, and assembling sample batches from various depths to test for systematic laboratory effects. Pollen grains and spores were identified using the University of Reading pollen type collection and the following sources of keys and photographs: Moore *et al* (1991); Reille (1992). The analysis procedure consisted of scanning the prepared slides, and recording the pollen grains and spores, until a maxximum count of 300 total land pollen was achieved. (Figures 7 & 8).

Diatom assessment/analysis

Eighteen sub-samples from borehole <NTBH03> and ten sub-samples from borehole <SSBH1C> were extracted for the assessment/analysis of diatoms. The diatom extraction involved the following procedures (Battarbee *et al.,* 2001):

1. Treatment of the sub-sample (0.2g) with Hydrogen peroxide (30%) to remove organic material and Hydrochloric acid (50%) to remove remaining carbonates
2. Centrifuging the sub-sample at 1200 for 5 minutes and washing with distilled water (4 washes)
3. Removal of clay from the sub-samples in the last wash by adding a few drops of Ammonia (1%)
4. Two slides prepared, each of a different concentration of the cleaned solution, were fixed in mounting medium of suitable refractive index for diatoms (Naphrax)

Duplicate slides each having two coverslips were made from each sample and fixed in Naphrax for diatom microscopy. The coverslip with the most suitable concentration of the sample preparation was selected for diatom evaluation. A large area of this coverslip was scanned for diatoms at magnifications of x400 and x1000 under phase contrast illumination using a Leica microscope. Diatom counting and analysis followed standard techniques (Battarbee *et al.* 2001). Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley *et* *al.* (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are discussed in part using the classification data in Denys (1992), Vos & de Wolf (1988, 1993) and the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}
2. Mesohalobian: 0.2-30 g l^{-1}
3. Oligohalobian - Halophilous: optimum in slightly brackish water
4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water
5. Halophobous: exclusively freshwater
6. Unknown: taxa of unknown salinity preference.

Diatom data were plotted using the 'C2' program (Juggins 2003). The results are displayed in Tables 6 and 7, and Figure 9.

Macrofossil extractions

A total of twenty small bulk samples from borehole <NTBH03> and twenty-two small bulk samples from borehole <STBH1C> were extracted for the recovery of macrofossil remains including waterlogged plant macrofossils, waterlogged wood and insects. The extraction process involved the following procedures: (1) removing a sample up to 10cm in thickness; (2) measuring the sample volume by water displacement, and (3) processing the sample by wet sieving using 300μm and 1mm mesh sizes.

Waterlogged plant macrofossil analysis (seeds & wood)

Identifications of the waterlogged seeds have been made using modern comparative material and reference atlases (Cappers *et al.* 2006, Schoch *et al*. 2004). A minimum of 10 waterlogged fragments per sample were identified. The attributes and general quality of fragment preservation was noted. Preparation and examination of fragments follows standard practices as described in Hather (2000). Waterlogged wood fragments were thin sectioned using a hand held razor blade and mounted on a slide. Wood charcoal fragments were pressure fractured and supported in a sand bath. Following preparation both forms of wood remains were examined at magnifications of up to x400. Specific attributes and features recorded during examination were the diameter of any twig wood and, as a means of determining relative maturity, the number of growth rings. Nomenclature follows Stace (2005), and the results are displayed in Tables 8 & 9.

Insect analysis

Identifications of the insect remains were made under a low powered stereo-microscope, and the identified (Tables 10). Identification and interpretation was based on modern comparative material and reference atlases (e.g. Kloet and Hincks, 1964-77; Kenward *et al.* 1986; Duff, 2008).

RESULTS AND INTERPRETATION OF THE GEOARCHAEOLOGICAL FIELD INVESTIGATIONS AND DEPOSIT MODELLING

The results of the fieldwork monitoring are displayed in Appendix 1. In the borehole monitored within the North Station (NSBH01), Made Ground was recorded down to a depth of -3.25m OD followed by blue-grey alluvium with dark brown pockets of peat and including fragments of wood. Sands and gravels commenced below -4.80m OD. The borehole within the North Intermediate Tower (NITBH02) was monitored down to a depth of 10m and was still within Made Ground. No further monitoring was carried out on this borehole, although the geotechnical borehole log, indicate that the Made Ground continued to a depth of 14.50m before reaching London Clay. The borehole from the North Tower (<NTBH01>) contained a very small amount of Made Ground (1.20m) overlying a thick sequence of alluvium including two substantial horizons of wood peat. Sands and gravels were encountered at -5.84m OD. This sequence was selected for further laboratory-based palaeoenvironmental investigations, and was re-cored as borehole <NTBH03> (a detailed description of which is provided in Table 1 and Figure 6). The borehole from the South Station (SSBH03) contained a thick horizon of contaminated Made Ground (5.20m) overlying alluvium from 0.14m OD and peat from -0.86 to -2.81m OD. Sands and Gravels were recorded below this. As a result of this *ca*. 2m thick horizon of peat, neighbouring borehole location <SSBH1C> was selected for laboratory based palaeoenvironmental investigations (displayed in Table 2 and Figure 6). As outlined within the introduction and methodology, these records were integrated with other geotechnical records to provide the following model of depositional history (Figure 5).

The London Clay bedrock (Unit 1) was recorded in 27 of the boreholes. It slopes down evenly on the south side of the river from -8.86m OD in borehole B4 to a maximum depth of -18.8m OD in the middle of the Thames channel in borehole B3, rising within the channel on its north side in borehole N11 to -8.39m OD. On the north side of the river the bedrock surface is uneven between -6.37m OD in borehole B8 and -8.72m OD in borehole B13.

The Shepperton Gravel (Unit 2) was recorded in all but one of the boreholes. On the south side of the river the surface of the gravel is rather uniformly between -2.25m OD (borehole 6a) and -3.45m (borehole 13a). It falls to -5.0m OD in borehole B1, but the gravel in borehole B1 is overlain by 3 feet (0.99m) of sand with a surface at -4.0m OD, and this sand may be part of the Shepperton Gravel rather than part of the overlying Holocene deposits. Within the river channel the gravel surface is at lower levels from *ca*. -5.0m OD (borehole N11) to just below -10.0m OD in the middle of the channel in borehole N12.

On the north side of the river the gravel has been heavily truncated in the seven boreholes in the vicinity of the Royal Victoria Dock. In six of the remaining nine boreholes on the north side of the river, the surface of the gravel, between -4.4m OD (borehole B24) and -5.88m OD (borehole BH03), is generally lower than it is on the south side of the river by about 2m. This difference resembles the situation recorded by Gibbard (1994, Fig.41) in a transect extending from the Greenwich area across the Thames into the Isle of Dogs. This transect shows the surface of the Shepperton Gravel in the Isle of Dogs, on the north side of the river, at least 2m below the level on the Greenwich side of the river. However in the present area of investigation there are two boreholes on the north side of the river (boreholes B19 and B22) in which the surface of the Shepperton Gravel is recorded at about the same level as it occurs on the south side of the river – between -2.5m OD and -3.0m OD, and in borehole B8 the surface of the gravel is recorded at +1.55m OD. In addition, previous investigations carried out by Wilkinson *et al*. (2000) to the *ca*. 500m to the east of the North Intermediate Tower also records the Shepperton Gravel surface around -2.50m OD, above which sediments dated to 12,800-11,690 accumulated. This suggests the presence here of a gravel 'high', broadly comparable in terms of elevation to the Bermondsey and Horseleydown gravel 'highs' (eyots) upstream in the Southwark area. These variations in the level of the surface of the Shepperton Gravel are consistent with observations elsewhere in the Thames valley. They indicate that at the beginning of the Holocene, the surface of the Shepperton Gravel formed the valley floor of the River Thames and was characterised by gravel bars generally elongated approximately parallel with the valley axis and separated by channels in which finer-grained sediments are often preserved. The relief on this surface is generally from 2.0m to 4.0m and exceptionally up to 6m.

Overlying the Shepperton Gravel in all the boreholes is a sequence of Holocene alluvial deposits. In 18 of the boreholes this sequence includes a peat unit (Unit 4). In six cases (boreholes SSBH02D, SSBH03, B29a, B8, SSDS04, NSBH01) the peat rests directly on the underlying gravel. In the remaining twelve boreholes the peat rests on the Lower Alluvium (Unit 3), either on sand (Unit 3a) (8 boreholes) or on alluvial silts and clays (Unit 3b) (4 boreholes). The Lower Alluvium, whether sand or silts and clays, is generally less than a metre thick (median value 0.6m). In borehole <NTBH03> the Lower Alluvium was a well-bedded tufa-rich sand with common detrital plant and mollusc remains.

Where peat is present it usually forms a single horizon varying in thickness from 2.43m in borehole NTBH02 on the north side of the river to 0.92m in borehole B4 on the south side (average for 11 boreholes with a single untruncated peat horizon: 1.60m, median 1.53m). The upper surface of these untruncated single peat horizons is at levels between -0.66m OD and -3.0m OD (average 1.06m, median 0.98m). The lowest level at which these single peat units are recorded is -4.84m OD in borehole NTBH02. In four boreholes, all on the north side of the river (B8, NTBH01, <NTBH03>, B24) two organic-rich/peat horizons are present. Two of these boreholes (NTBH01 and <NTBH03>) were immediately adjacent to one another and recorded closely similar alluvial sequences with a lower organic-rich deposit between -4.74m OD and -5.84m OD in Borehole NTBH01 and at a similar level in <NTBH03>. The greater part of this lower unit is therefore at a level below the lowest level at which the base of the single peat horizons was encountered.

In borehole B24 a lower peat horizon occupies a level (-1.6 to -4.0m OD) similar to the single peat horizons recorded elsewhere in the transect, but the Holocene sequence in borehole B24 includes an upper peat at a higher level, between +2.9m OD and +0.8m OD. Peat is also recorded in borehole B8 at a similar level where two thin peat horizons are present between +3.37m OD and +1.55m OD.

In the 11 boreholes with untruncated peat horizons and in all four of the boreholes with two peat horizons, the uppermost peat is overlain by the Upper Alluvium (Unit 5). Where this unit has been examined in detail in boreholes <SSBH1C> and <NTBH03>, it is a grey to olive coloured well-sorted silt with some evidence of soil forming processes in its upper part and scattered finely-divided detrital plant remains generally present. It is everywhere overlain by Made Ground and has undoubtedly been truncated in some places. However in fourteen boreholes the contact with the Made Ground is at a level between 3.33m OD (Borehole 13a) and 0.57m OD (Borehole <SSBH1C>) (average 1.77m OD, median 1.70m OD). A natural floodplain level close to 1.75m OD therefore seems likely.

RESULTS AND INTERPRETATION OF THE ORGANIC MATTER CONTENT DETERMINATIONS

The results of the organic matter content determinations for <NTBH03> (Table 3; Figure 6) indicate low values within the basal sand and gravel (<10%), before increasing slightly within the overlying units of silty, sandy organic-rich deposits (up to 25%) that continue to -4.80m OD. Within the overlying Peat, values reach up to 60% at -4.35m OD. Above these units was a thick sequence of alluvial silts and sands to -3.28m OD, which had a reflective low organic matter content (<6%). The overlying main peat unit spanned from -3.28m to -1.90m OD and contained values ranging between *ca*. 45% and 70% organic, with a peak at -2.70m OD. The final alluvial silts and clays were generally no more than 10% organic-rich.

The results of the <SSBH1C> organic matter determinations (Table 4; Figure 6) indicate low values within the basal sand and gravel (<4%) before gradually increasing from 15% to 33% through the overlying alternating units of peat and alluvium at -2.48m OD. Through the main peat (-2.48m to -0.93m OD) however, organic matter values varied between 40% and 70%, analogous to those recorded in <NTBH03>. The final units of alluvium and made ground contained generally limited organic matter content values of <10%.

RESULTS AND INTERPRETATION OF THE RADIOCARBON DATING

Borehole <NTBH03>

Four radiocarbon determinations were made on samples taken from borehole <NTBH03>. Identified waterlogged seeds of *Rumex/Polygonum* sp. from the silty sandy peat at the base of the <NTBH03> sequence (-5.63m to -5.68m OD) were radiocarbon dated to 10,740-10,510 cal BP (8790-8560 cal BC). At -4.68 to -4.76m OD a radiocarbon determination was made on *Alnus* sp. waterlogged wood which returned an age of 6850-6670 cal BP (4900-4720 cal BC). Above this, a radiocarbon determination was made on *Alnus* sp. catkins at -3.18 to -3.28m OD. This provided an age of 6290-6030 cal BP (4340-4080 cal BC). Finally, *Alnus* sp. waterlogged wood from the top of the peat (-1.95m to -2.00m OD) was radiocarbon dated to 3030-2870 cal BP (1080-920 cal BC). The δ13C (‰) values are consistent with that expected for material from peat sediments, and there is no evidence for mineral or biogenic carbonate contamination. These results therefore indicate alluvial deposition and peat accumulation took place at the site between at least the Early Mesolithic and Late Bronze Age/Early Iron Age cultural periods.

However, the radiocarbon determinations made within Borehole <NTBH03> are of note, particularly when compared with those made at West Silvertown (Wilkinson *et al*., 2000). At West Silvertown, the surface of the Shepperton Gravel was recorded around -2.50m OD, above which sediments dated to 12,800-11,690 accumulated. This depth is approximately 3m higher than within borehole <NTBH03> above which sediments of 10,740-10,510 cal BP (approximately 1000-2000 years younger) accumulated. In addition, the two dates at -4.68 to -4.76m OD (6850-6670 cal BP) and -3.18 to -3.28m OD (6290-6030 cal BP) are of interest as they are separated by *ca*. 1.5m yet both date within 600 years of each other. It is considered likely that the lower of these two dates is likely to be incorrect, but for unknown reasons.

Borehole <SSBH1C>

Alnus waterlogged wood from the peat at the base of <SSBH1C> (-3.01 to -3.06m OD) was radiocarbon dated to 5580-5310 cal BP (3630-3360 cal BC). At -2.01 to -2.08m OD a radiocarbon determination was made on *Alnus* sp. waterlogged wood which returned an age of 3450-3270 cal BP (1500-1320 cal BC). The top of the peat at -0.98 to -1.03m OD was radiocarbon dated to 3380-3210 cal BP (1430-1260 cal BC). The δ13C (‰) values are consistent with that expected for Peat sediment, and there is no evidence for mineral or biogenic carbonate contamination. These results therefore indicate alluvial deposition and peat accumulation took place at the site between at least the Neolithic and Late Bronze Age cultural periods.

However, the radiocarbon determinations at -2.01 to -2.08m OD (3450-3270 cal BP) and -0.98 to -1.03m OD (3380-3210 cal BP) are less than 100 years different despite being separated by 1m of peat. An average accumulation rate for peat is often considered to be 1m per 1000 years, and thus it appears that one of these results is incorrect. On the basis of other radiocarbon determinations from the base of the main Peat within the Lower Thames Valley, it appears most likely that the lowermost determination is incorrect, although the reasons for this are unclear.

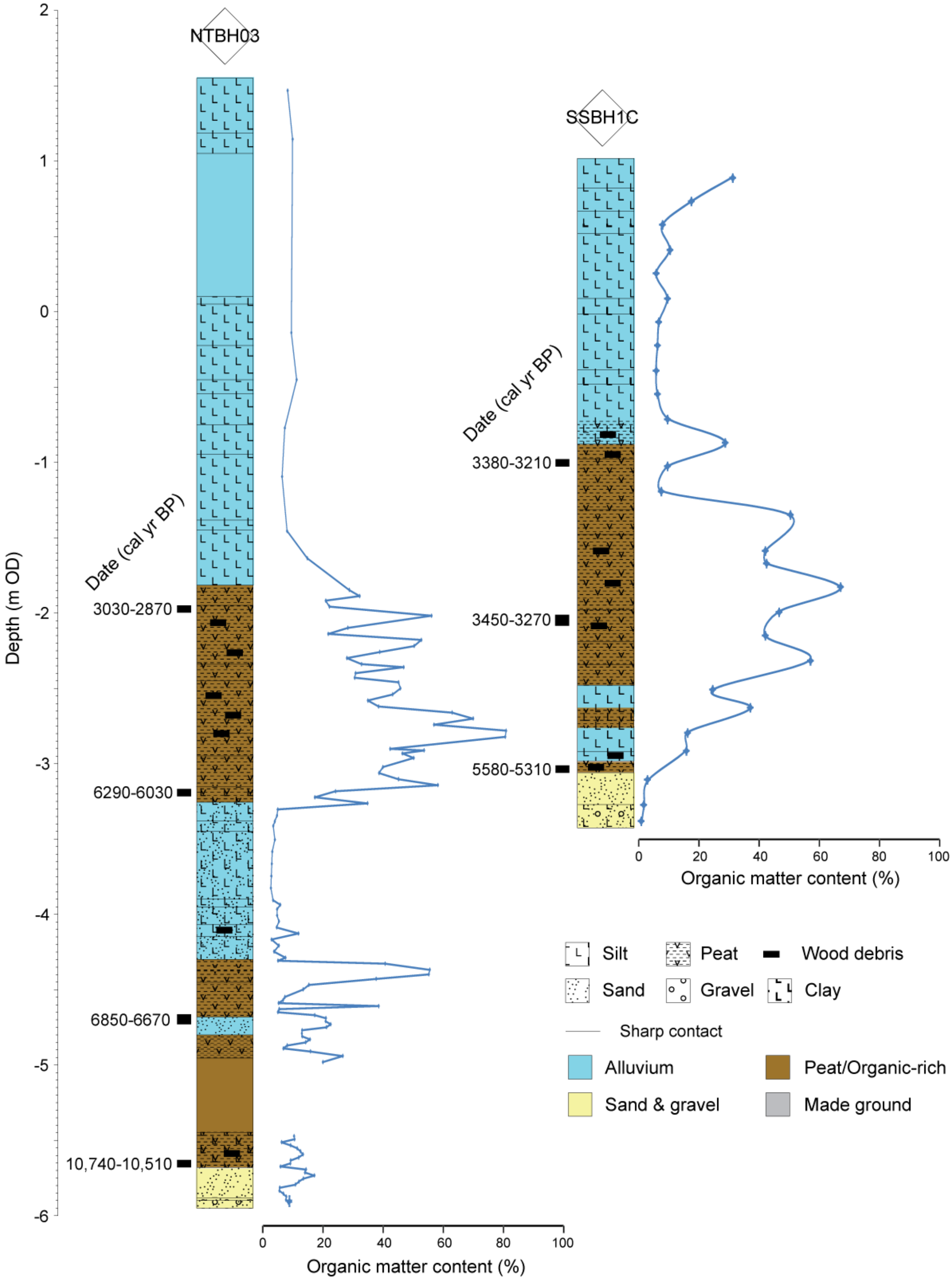


Figure 6: Results of the <NTBH03> and <SSBH1C> lithostratigraphic analysis, incorporating lithostratigraphy and organic matter content plotted with associated radiocarbon dates

Table 1: Results of the laboratory-based lithostratigraphic description of borehole NTBH03, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Composition
2.75 to 1.55	Made Ground
1.55 to 1.18	2.5Y4/1 dark grey with black flecks; very well sorted silt; massive; common detrital plant remains increasingly common downward; no acid reaction.
1.18 to 1.05	Olive brown silt; common detrital plant remains.
1.05 to 0.10	No retrieval
0.10 to 0.05	Irregular mass of plant-rich silt.
0.05 to -0.22	5Y3/1 very dark grey passing down gradually to 2.5Y4/4 olive brown, black flecks; very well sorted silt; massive passing down to blocky/crumby; root channels common in lower olive brown part; common root remains; vivianite as small (<1mm) white crystal clusters; strong acid reaction.
-0.22 to -0.45	Grey silt oxidising to olive brown with black flecks.
-0.45 to -0.54	5Y4/1 dark grey and 2.5Y4/4 olive brown; very well sorted silt; blocky/crumby; scattered root channels and root remains; scattered detrital plant remains; moderate acid reaction; well-marked transition to:
-0.54 to -0.75	Gley 1.4/1 dark grey; very well sorted silt; massive; scattered detrital plant remains; no acid reaction.
-0.75 to -0.95	Olive brown silt.
-0.95 to -1.37	Gley 1.4/1 dark grey with Fe staining on structural surfaces; very well sorted silt; massive; scattered detrital plant remains; vivianite as small (<1mm) white crystal clusters and coating some structural surfaces.
-1.37 to -1.45	Grey silt with Fe stained structural surfaces.
-1.45 to -1.82	5Y4/1 dark grey; very well sorted silt; massive; detrital plant remains increasingly common downward; wood debris increasingly common downward; no acid reaction.
-1.82 to -1.95	Peat
-1.95 to -2.34	Peat with round wood (up to 40mm Ø).
-2.34 to -2.45	Woody peat.
-2.45 to -2.80	Peat with common wood debris.
-2.80 to -2.95	Woody peat.
-2.95 to -3.16	Peat with wood debris; well-marked transition to:
-3.16 to -3.26	Mixture of wood-rich silt and peat in large (80mm) interpenetrating masses; very sharp contact with:
-3.26 to -3.37	5Y4/1 dark grey; silt and silty fine sand; unevenly bedded – alternations of silt and silty fine sand with individual beds 2-3mm thick; root channels with scattered *in situ* vertical root remains; scattered detrital plant remains; moderate acid reaction.
-3.37 to -3.45	Organic silty sand.
-3.45 to -3.90	5Y4/1 dark grey; well sorted silt and fine sand; bedded – alternations of silt and silty fine sand with individual beds varying from 2-10mm thick; root channels with scattered in situ vertical roots; scattered detrital plant remains; small piece of round wood(10mm Ø); weak acid reaction.
-3.90 to -3.95	organic silty sand.
-3.95 to -4.07	5Y3/2 dark olive grey; well sorted slightly silty fine sand; massive; scattered broken mollusc shell; strong acid reaction; very sharp inclined contact with:
-4.07 to -4.15	Mass of wood - ?root wood; very sharp horizontal contact with:
-4.15 to -4.30	5Y4/1 dark grey; silt and silty fine sand; unevenly bedded - alternations of silt and silty fine sand with individual beds varying from 2-10mm thick;

	scattered detrital plant remains.
-4.30 to -4.45	Peat
-4.45 to -4.68	Black with white vivianite flecks; well humified peat; lenses of blue vivianite; very sharp contact with:
-4.68 to -4.80	5Y4/2 olive grey; fine to medium tufa-rich sand; massive; scattered detrital plant remains; scattered broken mollusc shell; strong acid reaction.
-4.80 to -4.95	Organic-rich sediment
-4.95 to -5.45	No retrieval
-5.45 to -5.68	Dark brown to black; wet mixture of organic-rich sediment, silt and wood debris becoming firmer and more sandy downward; gradual transition to:
-5.68 to -5.88	5Y3/1 very dark grey to black; silty fine sand with bed of tufa-rich coarser sand at -5.81 to -5.83m OD; horizontally bedded; common detrital plant remains; scattered broken mollusc shell; strong acid reaction; well-marked transition to:
-5.88 to -5.90	Silty sandy gravel
-5.90 to -5.95	Sandy gravel/gravelly sand.

Table 2: Results of the laboratory-based lithostratigraphic description of borehole <SSBH1C>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Composition
5.72 to 1.02	Made ground
1.02 to 0.83	5Y4/2 olive grey to black with black flecks; well sorted gritty silt; massive; root channels; Charcoal; CBM; coal dust; piece of coke (50mm) at 0.84m OD; no acid reaction; well-marked transition to:
0.83 to 0.67	5Y4/2 olive grey; well sorted silt; coarse bedding with horizontal partings marked by laminated plant material; scattered root channels and root remains; charcoal; CBM; no acid reaction.
0.67 to 0.52	Olive silty clay
0.52 to 0.18	5Y4/2 olive grey with black patches and flecks; very well sorted silt; massive; common Fe-coated root channels and common root remains; faunal burrows; scattered detrital plant remains; moderate acid reaction.
0.18 to 0.02	Olive silty clay
0.02 to -0.37	5Y4/3; very well sorted silt; massive; root channels; no acid reaction; tarry contamination coating structural and other surfaces.
-0.37 to -0.48	Olive silty clay with tarry contamination
-0.48 to -0.88	5Y4/3 olive with black flecks; very well sorted silt becoming slightly peaty below -0.72m OD with wood debris; massive; root channels and scattered root remains; scattered detrital plant remains; no acid reaction; tarry contamination coating structural and other surfaces.
-0.88 to -0.98	peat with branch wood
-0.98 to -1.32	10YR2/2 very dark brown; peat with common wood debris
-1.32 to -1.48	peat with branch wood
-1.48 to -1.98	10YR2/2 very dark brown; peat with round wood (up to 35mm Ø).
-1.98 to -2.19	10YR2/2 very dark brown; incoherent mixture of peat and round wood (up to 40mm Ø) - ? drilling spoil; sharp contact with:
-2.19 to -2.34	10YR2/2 very dark brown; peat; horizontal laminations.
-2.34 to -2.48	Woody peat with contorted partings of grey silt.
-2.48 to -2.82	5Y3/2 dark olive grey; very well sorted silt with irregular inclusion of peat between -2.68m and -2.81m OD.
-2.82 to -2.98	Dark olive silt with scattered wood debris.
-2.98 to -3.06	Peat with common wood debris; uneven sharp contact with:

-3.06 to -3.27	5Y4/1 dark grey; very well sorted fine sand; no acid reaction; sharp contact with:
-3.27 to -3.43	2.5Y4/4 olive brown; slightly silty sandy gravel of sub-angular and well-rounded flint clasts (up to 40mm).

Table 3: Results of the borehole <NTBH03> organic matter determinations, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)		Organic matter content (%)	Depth (m OD)		Organic matter content (%)
From	To		From	To	
1.46	1.45	8.09	-4.03	-4.04	5.10
1.14	1.13	9.80	-4.07	-4.08	4.32
-0.14	-0.15	9.37	-4.11	-4.12	11.83
-0.45	-0.46	11.20	-4.15	-4.16	2.56
-0.77	-0.78	7.12	-4.19	-4.20	5.07
-1.09	-1.10	6.19	-4.23	-4.24	3.42
-1.45	-1.46	7.90	-4.27	-4.28	7.35
-1.63	-1.64	14.87	-4.29	-4.30	4.77
-1.84	-1.85	29.32	-4.31	-4.32	41.67
-1.88	-1.89	32.90	-4.35	-4.36	57.06
-1.91	-1.92	21.21	-4.38	-4.39	56.72
-1.95	-1.96	22.48	-4.41	-4.42	38.57
-2.01	-2.02	57.67	-4.45	-4.46	15.41
-2.09	-2.10	28.83	-4.48	-4.49	13.45
-2.13	-2.14	22.08	-4.53	-4.54	7.16
-2.17	-2.18	54.13	-4.55	-4.56	6.52
-2.21	-2.22	51.67	-4.57	-4.58	4.98
-2.25	-2.26	39.79	-4.59	-4.60	39.45
-2.29	-2.30	28.49	-4.61	-4.62	5.20
-2.33	-2.34	33.54	-4.63	-4.64	4.75
-2.35	-2.36	48.06	-4.65	-4.66	17.41
-2.39	-2.40	31.50	-4.67	-4.68	21.28
-2.42	-2.43	31.19	-4.69	-4.70	21.20
-2.45	-2.46	46.29	-4.71	-4.72	22.92
-2.49	-2.50	46.92	-4.73	-4.74	21.46
-2.53	-2.54	44.27	-4.75	-4.76	13.08
-2.57	-2.58	35.72	-4.77	-4.78	12.98
-2.61	-2.62	39.42	-4.79	-4.80	13.12
-2.65	-2.66	64.76	-4.81	-4.82	15.79
-2.69	-2.70	72.00	-4.83	-4.84	14.29
-2.73	-2.74	58.50	-4.85	-4.86	7.95
-2.77	-2.78	83.33	-4.87	-4.88	6.61
-2.81	-2.82	83.05	-4.89	-4.90	15.96
-2.89	-2.90	43.40	-4.92	-4.93	27.08
-2.90	-2.91	55.09	-4.96	-4.97	20.24
-2.92	-2.93	47.61	-5.45	-5.46	10.31

-2.95	-2.96	51.51
-3.01	-3.02	40.92
-3.05	-3.06	39.57
-3.09	-3.10	46.27
-3.13	-3.14	59.86
-3.17	-3.18	24.59
-3.21	-3.22	17.45
-3.25	-3.26	35.61
-3.29	-3.30	4.70
-3.33	-3.34	4.44
-3.37	-3.38	3.66
-3.40	-3.41	3.14
-3.49	-3.50	3.70
-3.57	-3.58	2.80
-3.65	-3.66	2.64
-3.73	-3.74	2.49
-3.81	-3.82	2.34
-3.89	-3.90	3.08
-3.92	-3.93	5.56
-3.95	-3.96	4.47
-3.99	-4.00	4.47
-5.47	-5.48	10.49
-5.49	-5.50	6.00
-5.51	-5.52	9.11
-5.53	-5.54	11.40
-5.55	-5.56	12.48
-5.57	-5.58	13.37
-5.59	-5.60	11.92
-5.61	-5.62	9.15
-5.63	-5.64	9.03
-5.65	-5.66	5.62
-5.67	-5.68	14.42
-5.69	-5.70	14.03
-5.71	-5.72	17.32
-5.73	-5.74	13.52
-5.75	-5.76	11.97
-5.77	-5.78	10.78
-5.79	-5.80	5.39
-5.81	-5.82	5.28
-5.83	-5.84	6.61
-5.85	-5.86	7.66
-5.87	-5.88	7.52
-5.89	-5.90	8.36

Table 4: Results of the borehole <SSBH1C> organic matter determinations, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)		Organic matter content (%)
From	To	
0.90	0.89	31.22
0.74	0.73	17.60
0.58	0.57	7.83
0.42	0.41	10.30
0.26	0.25	5.84
0.10	0.09	9.52
-0.07	-0.08	6.78
-0.23	-0.24	6.31
-0.39	-0.40	5.75
-0.55	-0.56	6.37
-0.71	-0.72	9.78
-0.87	-0.88	28.84
-1.03	-1.04	9.44
-1.19	-1.20	7.65
-1.35	-1.36	50.36
-1.59	-1.60	42.12
-1.67	-1.68	42.65
-1.83	-1.84	67.04
-1.99	-2.00	46.63
-2.15	-2.16	42.10
-2.31	-2.32	57.01
-2.51	-2.52	24.53
-2.63	-2.64	37.13
-2.79	-2.80	16.26
-2.91	-2.92	15.72
-3.11	-3.12	3.08
-3.27	-3.28	1.87
-3.38	-3.39	1.07

Table 5: Results of the borehole <NTBH03> and <SSBH1C> radiocarbon dating, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Laboratory code / Method	Borehole number	Material and location	Depth (m OD)	Uncalibrated radiocarbon years before present (yr BP)	Calibrated age BC/AD (BP) (2-sigma, 95.4% probability)	δ13C (‰)
Beta-301323	<NTBH03>	*Alnus* sp. waterlogged wood at top of highest Peat	-1.95 to -2.00	2840 ± 30	1080-920 cal BC (3030-2870 cal BP)	-27.4
SUERC-37743 (GU26330)	<NTBH03>	*Alnus sp.* catkins at base of main Peat	-3.18 to -3.28	5395 ± 30	4340-4080 cal BC (6290-6030 cal BP)	-27.3
SUERC-37826 (GU26332)	<NTBH03>	*Alnus* sp. waterlogged wood within lower Peat	-4.68 to -4.76	5925 ± 35	4900-4720 cal BC (6850-6670 cal BP)	-28.7
Beta-301234	<NTBH03>	*Alnus* sp. waterlogged wood at base of lowest Peat	-5.63 to -5.68	9400 ± 50	8790-8560 cal BC (10,740-10,510 cal BP)	-26.2
Beta-301231	<SSBH1C>	*Alnus* sp. waterlogged wood at top of highest Peat	-0.98 to -1.03	3080 ± 40	1430-1260 cal BC (3380-3210 cal BP)	-27.8
SUERC-37825 (GU26331)	<SSBH1C>	*Alnus* sp. waterlogged wood midway through main Peat	-2.01 to -2.08	3145 ± 35	1500-1320 cal BC (3450-3270 cal BP)	-27.7
Beta-301232	<SSBH1C>	*Rumex*/*Polygonum* sp. seeds at base of lowest Peat	-3.01 to -3.06	4680 ± 40	3630-3360 cal BC (5580-5310 cal BP)	-29.4

RESULTS AND INTERPRETATION OF THE POLLEN ANALYSIS

Results of the borehole <NTBH03> pollen analysis

The pollen-stratigraphic diagram (Figure 7) has been divided into five Local Pollen Assemblage Zones (LPAZ's BH3-1 to BH3-5). Pollen concentration and preservation was variable throughout the sequence, but particularly in LPAZ's BH3-4 and BH3-5.

LPAZ BH3-1; -5.86m to *ca*. -5.25m OD; centred on 10,740-10,510 cal BP

Poaceae – Cyperaceae - *Pinus* - *Betula*

This zone is characterised by high values of herbaceous pollen taxa dominated by Poaceae (*ca*. 60%) and Cyperaceae (*ca*. 10%), with sporadic occurrences of other taxa including *Artemisia*, Lactuceae, *Rumex* undifferentiated, *Ranunculus* type, *Galium* type and *Mentha* type. Tree and shrub pollen are dominated by *Pinus* (10%) and *Betula* (5%), with increasing occurrences of *Alnus*, *Quercus*, *Tilia*, *Ulmus*, *Fraxinus*, *Corylus* type and *Salix* (all from absence/near absence to *ca*. 5%). Aquatic taxa were present throughout and in reasonable concentrations, dominated by *Typha latifolia* (5%) with *Sparganium* type (1%). Spores of *Dryopteris* type and *Polypodium vulgare* were present in limited concentrations (<3%).

LPAZ BH3-2; *ca*. -5.25m to -4.43m OD; centred on 6850-6670 cal BP

***Pinus* – Corylus type – Poaceae – Cyperaceae**

This zone is characterised by very high values of *Pinus* which decline through the zone (75% to <20%). This is reflected by rising *Corylus* type values (from 5% to 25%), with *Alnus*, *Quercus*, *Salix* (all <10%), *Tilia*, *Ulmus*, *Fraxinus*, *Betula* and *Sambucas nigra* (all <5%). Herbaceous taxa remain dominated by Poaceae and Cyperaceae (both up to 20%) with sporadic occurrences of Asteraceae, Lactuceae, Caryophyllaceae and *Ranunculus* type. Aquatic taxa are represented by *Sparganium* type which is present throughout the zone. Spores (including *Dryopteris* type and *Pteridium aquilinum*) are present throughout (*ca*. 5%).

LPAZ BH3-3; -4.43m to -3.16m OD; 6850-6670 to 6290-6030 cal BP

***Alnus* – *Quercus* – *Corylus* type**

This zone is characterised by high values of tree and shrub pollen dominated by *Alnus* (40%) with *Quercus* (20%), *Corylus* type (10%), *Pinus*, *Tilia*, *Ulmus*, *Fraxinus* (all <5%), *Betula*, *Hedera*, *Salix* (<2%) and sporadic occurrences of *Taxus*/cf *Taxus*. Herb pollen values are low, dominated by Poaceae, Cyperaceae and *Chenopodium* type (all ca. 5%) with Asteraceae, *Artemisia* and *Armeria maritima* A/B (<1%). Aquatic taxa were present throughout the zone in low concentrations, including *Sparganium* type and *Typha latifolia* (<1%). Spore values were very low (<2%) including *Dryopteris* type, *Polypodium vulgare* and *Pteridium aquilinum*.

LPAZ BH3-4; -3.16m to -2.43m OD; 6290-6030 to <3030-2870 cal BP

***Alnus – Quercus – Corylus* type**

This zone is a similar assemblage to that of LPAZ BH3-3, but is characterised by a decline in *Ulmus* (from 5% to <3%) at the base of the zone, with *Fraxinus* and *Quercus*, reflected by gradually increasing *Tilia* values. *Taxus* also occurred sporadically through the zone. The herbaceous pollen assemblage was characterised by a decline in *Chenopodium* type and Poaceae pollen values, whilst aquatics declined to absence. *Dryopteris* type and *Polypodium vulgare* spores increased through the zone.

LPAZ BH3-5; -2.43m to -1.81m OD; centred on 3030-2870 cal BP

***Alnus – Quercus – Corylus* type**

This zone is characterised by very low pollen concentrations, and an apparent gradual decline in tree and shrub pollen values. *Alnus* continues to dominate (30%) with *Quercus* (20%) and *Corylus* type (10%). *Pinus* values increase with *Salix*, whilst *Tilia*, *Ulmus*, cf *Taxus*, *Fraxinus*, *Hedera* and *Sambucas nigra* were all noted. The herbaceous pollen assemblage was dominated by Poaceae and Cyperaceae (5%) with Lactuceae and *Chenopodium* type (<5%). Aquatic taxa included *Menyanthes trifoliata* and *Sparganium* type, whilst spores included *Pteridium aquilinum* and *Dryopteris* type.

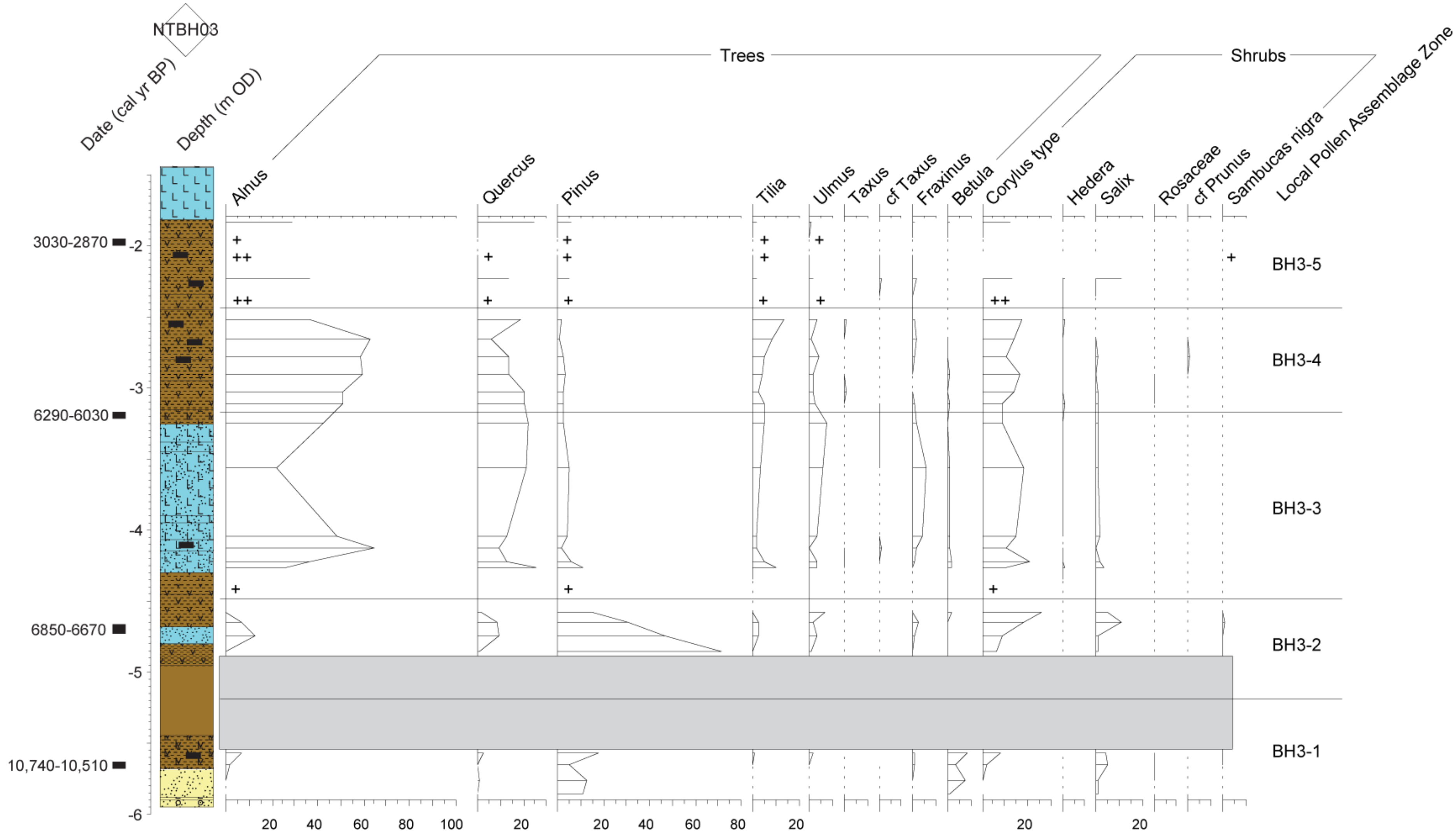


Figure 7: Pollen-stratigraphic diagram for borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

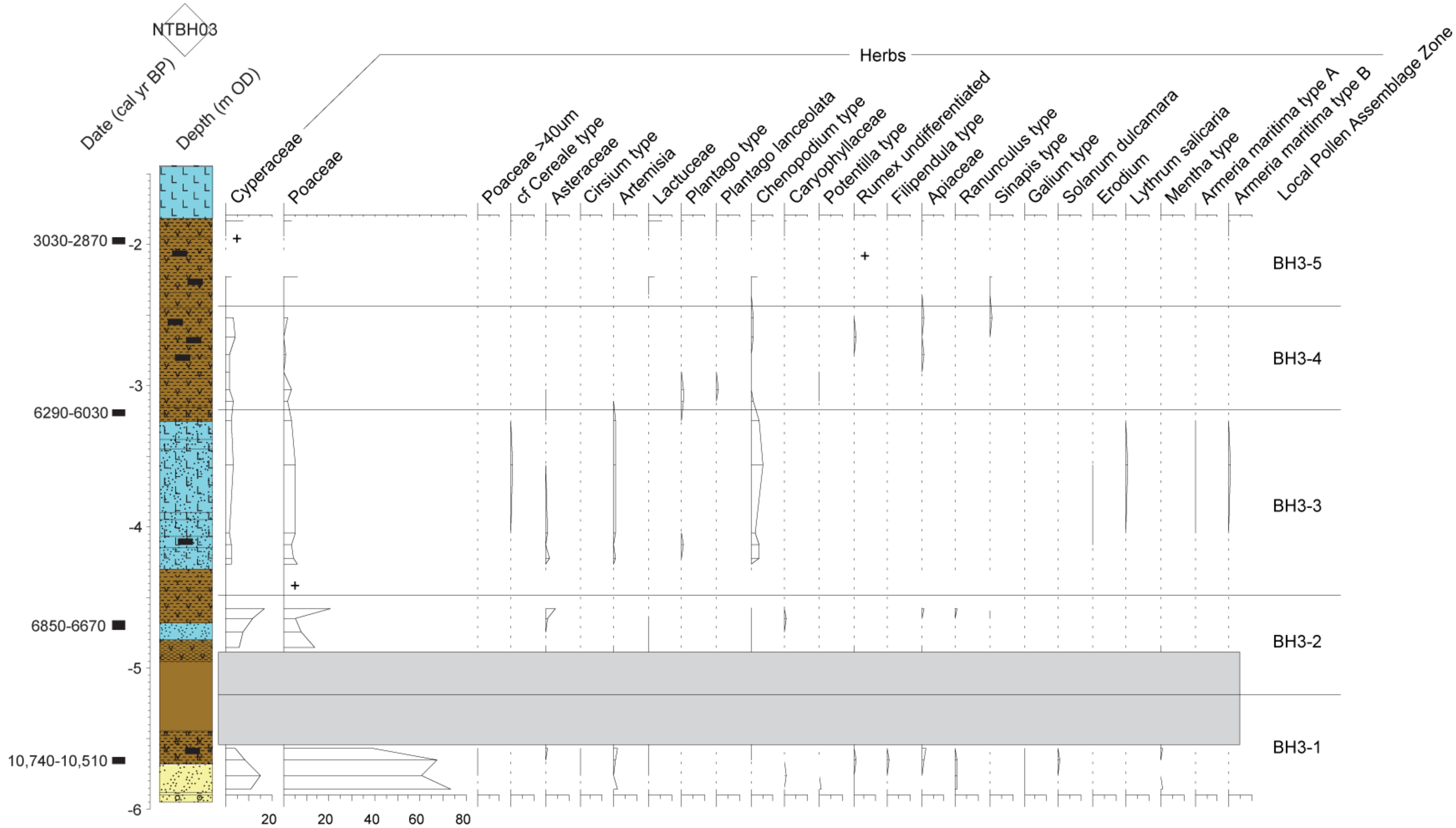


Figure 7: Pollen-stratigraphic diagram for borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

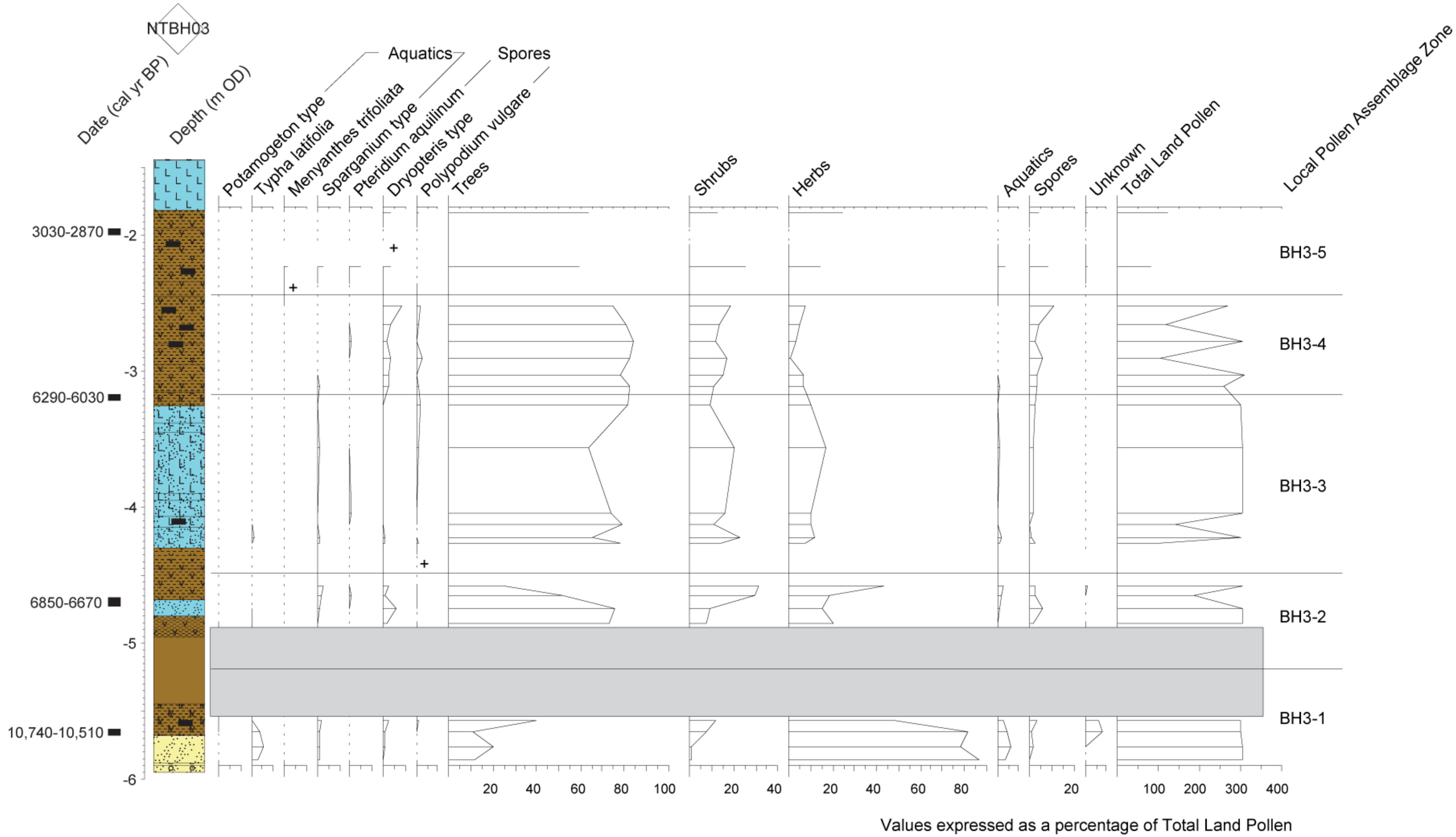


Figure 7: Pollen-stratigraphic diagram for borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Interpretation of the borehole <NTBH03> pollen analysis

The results of the pollen-stratigraphical analysis indicate that during LPAZ BH3-1, grasses (Poaceae) and (Cyperaceae) dominated the wetland environment, with other herbaceous and aquatic taxa such as bulrush (*Typha latifolia*), bur-reed (*Sparganium* type), buttercup/water crowfoot (*Ranunculus* type), water mint (*Mentha* type), mugwort (*Artemisia*), meadowsweet (*Filipendula* type) and docks/sorrels (*Rumex* undifferentiated). Woodland taxa included birch (*Betula*) and pine (*Pinus*) which were present throughout, whilst alder (Alnus), oak (*Quercus*), lime (*Tilia*), elm (*Ulmus*), ash (*Fraxinus*), e.g. hazel (*Corylus* type) and willow (*Salix*) appeared and increased towards the end of the zone. Where these woodland taxa were growing is more difficult to establish. Birch and Pine produce high quantities of pollen which are well documented for travelling long distances, and thus may have travelled some distance from source as opposed to originating from the wetland. Alder and willow most likely grew on the wetland when they appeared, whilst ash, hazel, oak, elm and hazel may have grown either within a wetland community, or on the dryland with lime (and probably birch and pine).

During LPAZ BH3-2, the pollen-stratigraphical analysis indicates a transition to a local environment dominated by pine, whilst grasses, sedges bur-reed and bulrush indicate the continuance of wetland habitats. The speed of this environmental transition is unknown due to the unfortunate lack of core retrieval between -4.95 and -5.45m OD. Within the upper half of the zone however, pine steadily declines and is gradually replaced by other trees and shrubs such as alder and willow which would have grown on the wetland, possibly with ash, hazel, elm and hazel. However, these latter tree taxa may also have grown on the dryland with lime, oak and some pine.

The transition to LPAZ BH3-3 is characterised by the further development of alder-dominated carr woodland on the wetland. The surface of the wetland was also populated by trees, shrubs and plants typical of marsh/fen environments such as willow, grasses, sedges, bur-reed and purple loosestrife (*Lythrum salicaria*). A grain of possible cereal pollen was also noted within the stratigraphic sequence, but because of its occurrence within a wetland context combined with its age, and isolated occurrence, its relation to human activity cannot be ascertained. In addition, grains with a similar morphology to that of cereal pollens are also known to be produced by wetland grasses such as *Glyceria* (e.g. Andersen, 1979). LPAZ BH3-3 is also strongly characterised by, the combined occurrence of herbaceous pollen taxa such as *Armeria maritima* types A & B (thrift), *Chenopodium* type (e.g. *Suaeda maritima* – annual seablite), Asteraceae (sea daisy) and *Erodium* (storksbill) which indicate an estuarine influence during this period. On the dryland, mixed deciduous-coniferous woodland continued to dominate.

During LPAZ BH3-4, alder dominated woodland continued to expand on the wetland, most likely in response to a renewed period of peat formation. This transition occurs in tandem with the decline of estuarine indicators such as *Chenopodium* type and *Armeria maritima*, which suggests a decreasing tidal influence at the site. This period is also characterised by a decline in *Ulmus* (elm) pollen at the beginning of the zone, which represents the decline of elm within the dryland, and possibly wetland woodland community. The elm decline is well recorded in pollen diagrams across the British Isles representing the large-scale decline of elm populations across during the Early Neolithic. At <NTBH03>, the decline occurs around 6290-6030 cal BP which is within the range of dates calculated for the British Isles by Parker *et al* (2002) where the reduction in pollen is recorded as commencing between 6343 and 6307 and continuing until 5420 and 5290 cal BP. Multiple reasons have been put forward for cause of the decline in elm populations, including disease and human activity. However, it is of note that at <NTBH03>, the decline occurs at the same time as wetland expansion.

Following the decline of elm, sporadic grains of *Taxus* (yew) pollen are recorded, most likely representing its growth nearby on the wetland surface within the alder dominated woodland. Yew is commonly recorded as a component of the wetland woodland along the Lower Thames Valley during the Neolithic cultural period, and the significance of the new findings from borehole <NTBH03> are discussed in more detail below. Finally, an unusual feature of the new pollen-stratigraphic diagram is the increase of *Tilia* (lime) percentage values towards the top of the zone. Unlike most arboreal taxa, the pollen from lime is entomophilous (insect pollinated), and thus does not travel far from source. Therefore the high concentrations of lime suggest that it was growing nearby on areas of dryland during this period.

During final LPAZ BH3-5, the vegetation history is difficult to reconstruct as a consequence of poor pollen preservation and concentration. However, it appears that alder carr woodland began to decline from the wetland surface. On the dryland, it appears that lime woodland declined, with only occasional grains of *Tilia* pollen recorded. The lime decline is another well-documented vegetation change across the British Isles. In this case, the date of the decline is less contemporaneous, ranging in date from 6420-6200 cal BP at Saham Mere (Bennett, 1988) to 1520-1000 cal BP at Epping Forest (Baker *et al.*, 1978). However, the majority of dates (including those of the Lower Thames Valley) range from 5000 to 3000 cal BP, equating to the Late Neolithic-Bronze Age cultural periods. Three hypotheses have been put forward for the cause of the decline in *Tilia*: (1) climatic cooling (Godwin, 1956); (2) soil deterioration due to waterlogging and peat formation (paludification; Waller, 1994a); and (3) human induced land clearance (Turner, 1962); these are discussed further below.

Results of the borehole <SSBH1C> pollen analysis

The pollen-stratigraphic diagram (Figure 8) has been divided into three Local Pollen Assemblage Zones (LPAZ's BH3-1 to BH3-5). Pollen concentration and preservation was better than in borehole <NTBH03>, but still declined within the uppermost zone.

LPAZ BH1C-1; -3.02m to -2.16m OD; 5580-5310 to 3450-3270 cal BP

Alnus –Quercus – Tilia

This zone is characterised by high values of tree and shrub pollen dominated by *Alnus* (40%) with *Quercus* (20%), *Tilia* (10% increasing to <35% at the top of the zone), *Corylus* type (10%), *Pinus*, *Ulmus*, *Fraxinus*, *Betula*, *Hedera*, *Salix* (<5%) with sporadic occurrences of Rosaceae *Taxus* and *Sambucas nigra* (<1%). Herbaceous taxa were dominated by Cyperaceae, Poaceae, *Chenopodium* type (<3%) with *Artemisia* and Lactuceae (<1%) and sporadic occurrences of Asteraceae, *Plantago* type and Caryophylllaceae. Aquatic pollen values were very low comprising only *Sparganium* type (<2%), whilst *Pteridium aquilinum*, *Dryopteris* type and *Polypodium vulgare* spores were present throughout (all <5%).

LPAZ BH1C-2; -2.16m to -1.20m OD; 3450-3270 to 3380-3210 cal BP

***Alnus – Quercus – Corylus* type**

This zone is characterised by changes in the arboreal pollen assemblage. *Alnus* values increase to ca. 50% whilst *Tilia* values decline to ca. 5%. *Taxus* also occurs regularly in the lower half of the zone (<5%) before declining to absence. All other tree, shrub and herbaceous pollen values remain unchanged from LPAZ BH1C-1. Aquatic pollen values remain very low and sporadic, but with a greater diversity of taxa including *Potamogeton* type, *Typha latifolia*, *Menyanthes trifoliata* and *Sparganium* type. Spore taxa are dominated by *Dryopteris* type and *Polypodium vulgare*, whilst *Pteridium aquilinum* declines.

LPAZ BH1C-3; -1.20m to -0.82m OD; centred on 3380-3210 cal BP

***Alnus* – Poaceae – *Chenopodium* type**

This zone is characterised by a decline in tree pollen values including *Alnus*, *Tilia*, *Ulmus* and *Fraxinus*. *Pinus* values increase to >5%, whilst other tree and shrub taxa remain unchanged from LPAZ BH1C-2. Herbaceous pollen values increase dominated by Poaceae, Cyperaceae, Lactuceae, *Chenopodium* type and *Sinapis* type (all 5-10%), with Astereae, cf *Cereale* type, *Plantago* type, Caryophyllaceae and Apiaceae (<2%). Aquatic pollen values are low but continuous, dominated by *Sparganium* type with *Typha latifolia*. Spore taxa comprise *Pteridium aquilnum*, *Dryopteris* type (both 5%) with *Polypodium vulgare* (<2%) and a single occurrence of Sphagnum.

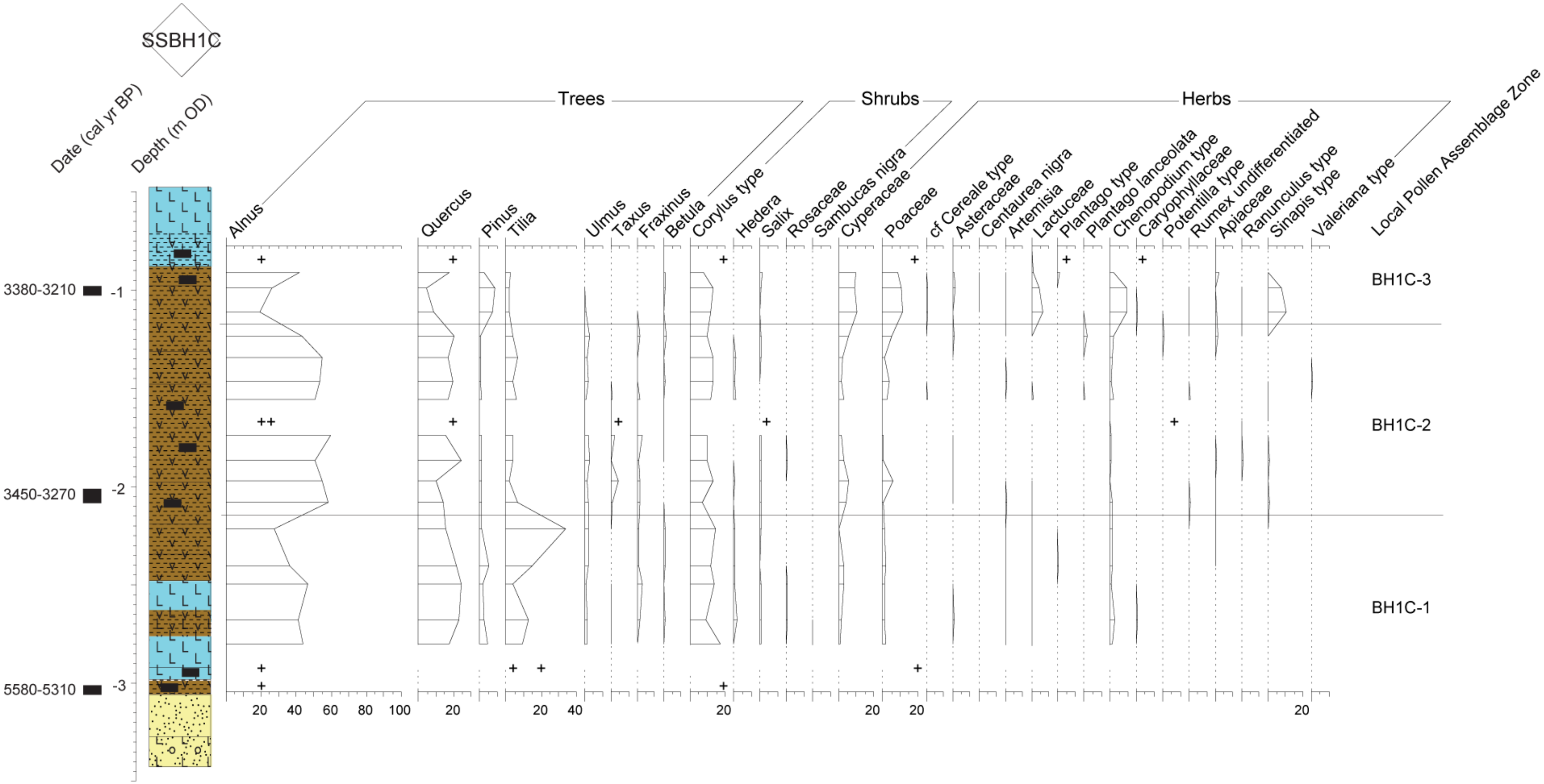


Figure 8: Pollen-stratigraphic diagram for borehole <SSBH1C>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

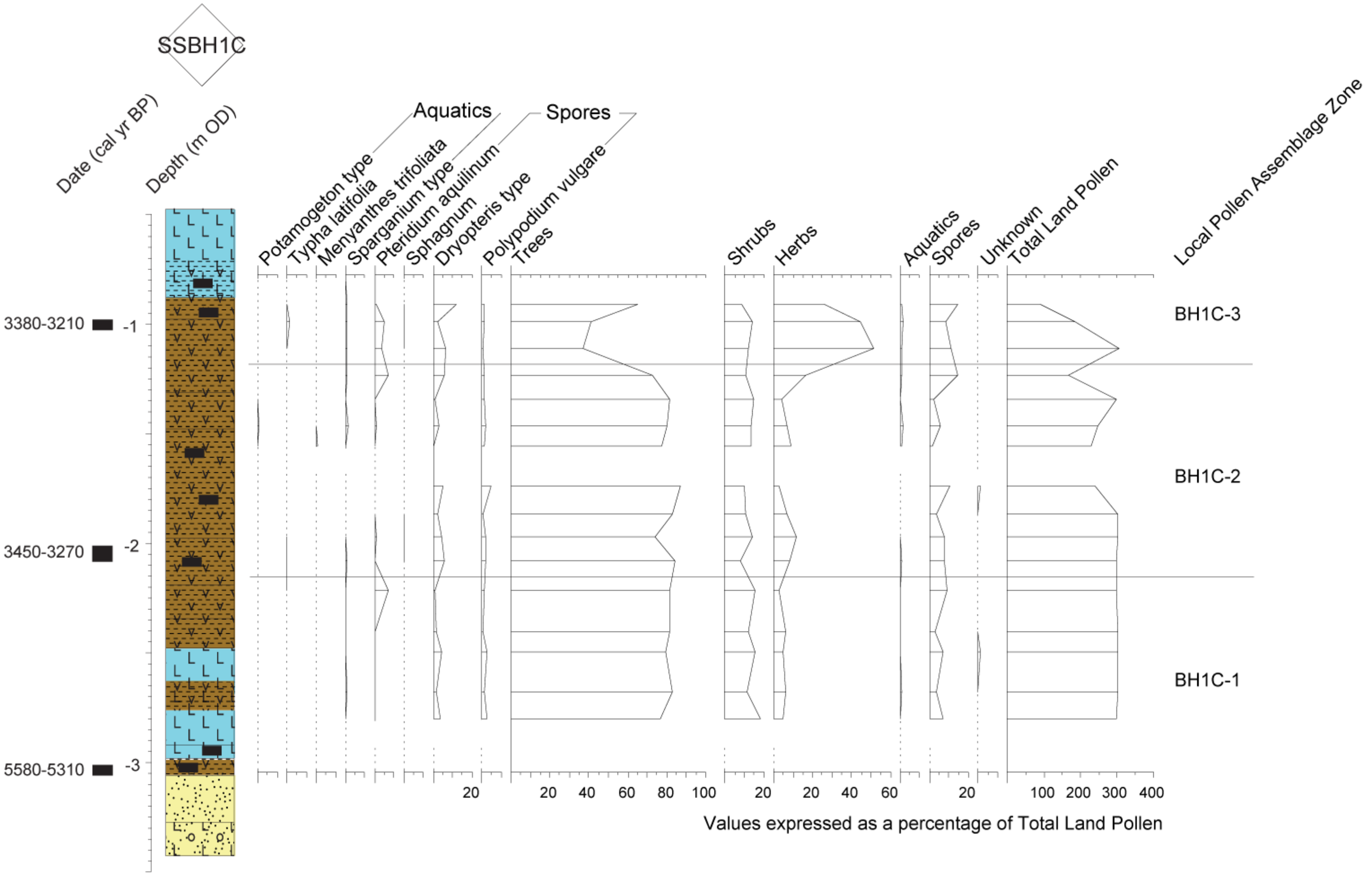


Figure 8: Pollen-stratigraphic diagram for borehole <SSBH1C>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Interpretation of the borehole <SSBH1C> pollen analysis

During LPAZ BH1C-1, the wetland was dominated by alder and willow woodland with a ground flora of sedges, grasses, and various herbs and aquatics such as daisies, pinks (Caryophyllaceae), dandelions (Lactuceae) and bur-reed. Elm, birch, ash, hazel and ivy (*Hedera*) may also have grown on the wetland within this woodland community, but could equally have grown on the dryland with oak and lime. The low concentrations of elm throughout the diagram, suggest that this sequence post-dates the well-documented elm decline (e.g. Parker *et al*., 2000). The concentrations of lime pollen towards the top of this zone are also important, since such high values suggest that areas of dryland woodland were growing nearby, or even at the site of deposition.

The transition to LPAZ BH1C-2 is characterised by the decline of lime and increase of alder pollen values. This transition was most likely caused by wetland expansion, since it follows the development of peat within the lithostratigraphic record. The zone is also characterised by an increase in yew pollen percentages, indicating its colonisation on the peat surface within the alder dominated woodland.

During the final period LPAZ BH1C-3, the pollen stratigraphic record indicates the decline of woodland on both the wetland and dryland surfaces. On the wetland, alder dominated woodland declines, as grasses, sedges and various herbaceous plants expand, most likely in response to wetter conditions. Indeed, the increase of taxa such as *Chenopodium* type, may suggest the growth of saline taxa nearby to the site (e.g. *Suaeda maritima* – annual seablite) and the influence of estuarine conditions. On the dryland, mixed deciduous woodland (dominated by oak and lime) declines as herbaceous taxa increase. The presence of cf *Cereale* type, *Centaurea nigra*, *Sinapis* type and possibly *Chenopodium* type (e.g. *Chenopodium album* - fat hen), may be indicative of clearance for agricultural purposes. Whether the decline of wetland and dryland woodland is linked is uncertain, but does seem to be a common feature of woodland within pollen-stratigraphic diagrams from the Lower Thames Valley (discussed further below).

RESULTS AND INTERPRETATION OF THE DIATOM ASSESSMENT

Eighteen sub-samples from borehole <NTBH03> and ten sub-samples from borehole <SSBH1C> were extracted for the assessment/analysis of diatoms. Of these samples, 10 samples from borehole <NTBH03> and five samples from <SSBH1C> contained no remains suitable for identification (Tables 6 & 7). The very poor preservation, absence or low numbers of diatoms in the majority of the slides prepared from the two London Cable Car Route borehole sequences, and the probable over-representation of robust taxa, can be attributed to taphonomic processes. The loss of diatom assemblages may be the result of silica dissolution caused by factors such as high sediment alkalinity, very high acidity, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, exposure of sediment to the air, or physical damage to diatom valves from abrasion or wave action (e.g. Flower 1993; Ryves *et al.* 2001).

However, diatom assemblages suitable for percentage diatom analysis were present in four samples from <NTBH03>, whilst five samples from <SSBH1C> and four samples from <NTBH03> were suitable for a detailed assessment. The diatom species recorded in the selected samples for which percentage diatom counting was not possible are shown in Tables 6 & 7 along with their halobian classifications. Figure 9 presents diatom species and summary halobian group diagrams for the slides prepared that have diatom assemblages suitable for percentage diatom analysis.

<NTBH03>

No identifiable diatom valves or valve fragments were identified in the slides from the base of the <NTBH03> sequence between at -5.77 and -4.25m OD. The diatom assemblages analysed from -4.21m OD, -4.12m OD and -4.03m OD (Figure 9, Table 6) are dominated by polyhalobous taxa, which at -4.21m OD and -4.03m OD comprise 66% to 74% of the diatom assemblages. The most common of the marine taxa in the three samples are *Rhaphoneis surirella, Rhaphoneis amphiceros*, *Rhaphoneis minutissima, Cymatosira belgica* and *Paralia sulcata.* Mesohalobous taxa such as *Cyclotella striata* and *Nitzschia navicularis* are present in lower numbers. The cumulative total of mesohalobous taxa is 13% and 15% at -4.21m OD and at -4.03m OD respectively. There are low numbers of oligohalobous indifferent diatoms with totals of only 2% to 5% respectively at these depths. The diatom assemblages here represent marine-brackish conditions.

Diatom numbers are extremely low and the assemblages are very poorly preserved at -3.17m OD and -3.01m OD. With the possible exception of a fragment of the polyhalobous to mesohalobous species *Pseudopodosira westii* at -3.01m OD the diatom fragments were not identifiable to the generic or species level.

The diatom slides counted from -1.92m OD and from -1.81m OD (Figure 9) are dominated by mesohalobous taxa which comprise 49% to 50% of the total flora. The most common mesohalobous diatom is the estuarine planktonic species *Cyclotella striata*. A number of mesohalobous benthic taxa are also present; these include *Nitzschia punctata, Nitzschia granulata* and *Nitzschia navicularis*. At -1.92m OD and -1.81m OD the polyhalobous and polyhalobous to mesohalobous diatom groups comprise approximately 20% and less than 5% of the assemblages respectively. The most common marine diatoms are *Paralia sulcata* with *Cymatosira belgica, Rhaphoneis* spp. and *Trachyneis aspera* are also present. The polyhalobous to mesohalobous diatom *Actinoptychus undulatus* is present. There are also relatively high percentages of oligohalobous indifferent taxa in these slides, increasing from 13% to 22% of the total diatoms. The freshwater taxa include *Cocconeis disculus, Cocconeis placentula, Fragilaria brevistriata, Fragilaria construens* var. *venter, Fragilaria lapponica, Fragilaria pinnata, Gyrosigma attenuatum* and *Synedra ulna*. The *Fragilaria* taxa have wide salinity tolerance ranges. The diatom assemblages found in the upper part of <NTBH03> (Figure 9), like those assemblages analysed lower down in the sequence indicate that the sedimentary environment was a tidal one. The relative increase in mesohalobous species, particularly estuarine plankton along with the increase in the number of oligohalobous indifferent diatoms, and the decrease in allochthonous polyhalobous diatoms may indicate a more stable sedimentary environment with reduced inputs of diatoms from the outer estuary. In the top slide from <NTBH03> (-1.68m OD) the mesohalobous benthic species *Nitzschia navicularis* was recorded (Table 6).

In summary, Diatoms are poorly preserved in the majority of slides examined from the <NTBH03> sequence. All of the samples analysed are consistent with an estuarine environment. The changes in the proportions of allochthonous marine diatoms, planktonic and benthic estuarine taxa, and oligohalobous indifferent diatoms tolerant of higher salinities suggest changes in the aquatic environment from the base to the top of the sequence (Figure 9). These changes may indicate a more stable sedimentary environment, with smaller inputs of diatoms from the outer estuary in the top samples that were analysed. However, the diatom assemblages at -1.92m OD and -1.81m OD continue to represent tidal environments.

<SSBH1C>

None of the samples from <SSBH1C> were suitable for percentage diatom counting. The results of semi-quantitative counting are shown in Table 7. In the top three samples with diatomaceous remains (-0.68m OD, -0.82m OD and -2.50m OD), the most common diatom is the benthic mesohalobous species *Nitzschia navicularis*. The polyhalobous planktonic diatom *Paralia sulcata* is also present at -0.82m OD. A fragment that is probably from *Nitzschia navicularis* is also present on the slide from -2.59m OD. The estuarine planktonic species *Cyclotella striata* is present at -3.02m OD with polyhalobous *Rhaphoneis* spp. A fragment of the heavily silicified, robust oligohalobous indifferent diatom *Synedra acus* is also present at -3.02m OD. The diatoms present throughout the <SSBH1C> sequence represent brackish-marine, estuarine conditions. However, the quality of diatom preservation is extremely poor and no further interpretation of these diatom assemblages is possible.

Table 6: Results of the <NTBH03> detailed diatom assessment, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Diatom Taxon/ Sample Depth (m) OD	**-1.68 to -1.69**	**-3.01 to -3.02**	**-3.17 to -3.18**	**-3.35 to -3.36**	**-4.12 to -4.13**	**-4.21 to -4.22**	**-4.25 to -4.26**	**-4.34 to -4.35**	**-4.56 to -4.57**	**-4.63 to -4.64**	**-4.68 to -4.69**	**-4.74 to -4.75**	**-4.85 to -4.86**	**-5.65 to -5.66**	**-5.76 to -5.77**
Polyhalobous															
Cymatosira belgica					1										
Paralia sulcata	2														
Podosira stelligera	1														
Rhaphoneis amphiceros/surirella					3										
Rhaphoneis surirella					3										
Polyhalobous to Mesohalobous															
Pseudopodosira westii	1	cf			1										
Mesohalobous															
Caloneis westii					1										
Cyclotella striata	2				2										
Nitzschia punctata	cf														
Nitzschia granulata	1														
Nitzschia navicularis	2				2										
Oligohalobous Halophilous															
Navicula cincta					1										
Oligohalobous Indifferent															
Ellerbeckia arenaria	1														
Synedra ulna	1														
Unknown Salinity Group															
Inderminate centric sp.	1	1													
Inderminate pennate sp.			1												
Thalassiosira sp.	1														
Unknown naviculaceae	1		cf												

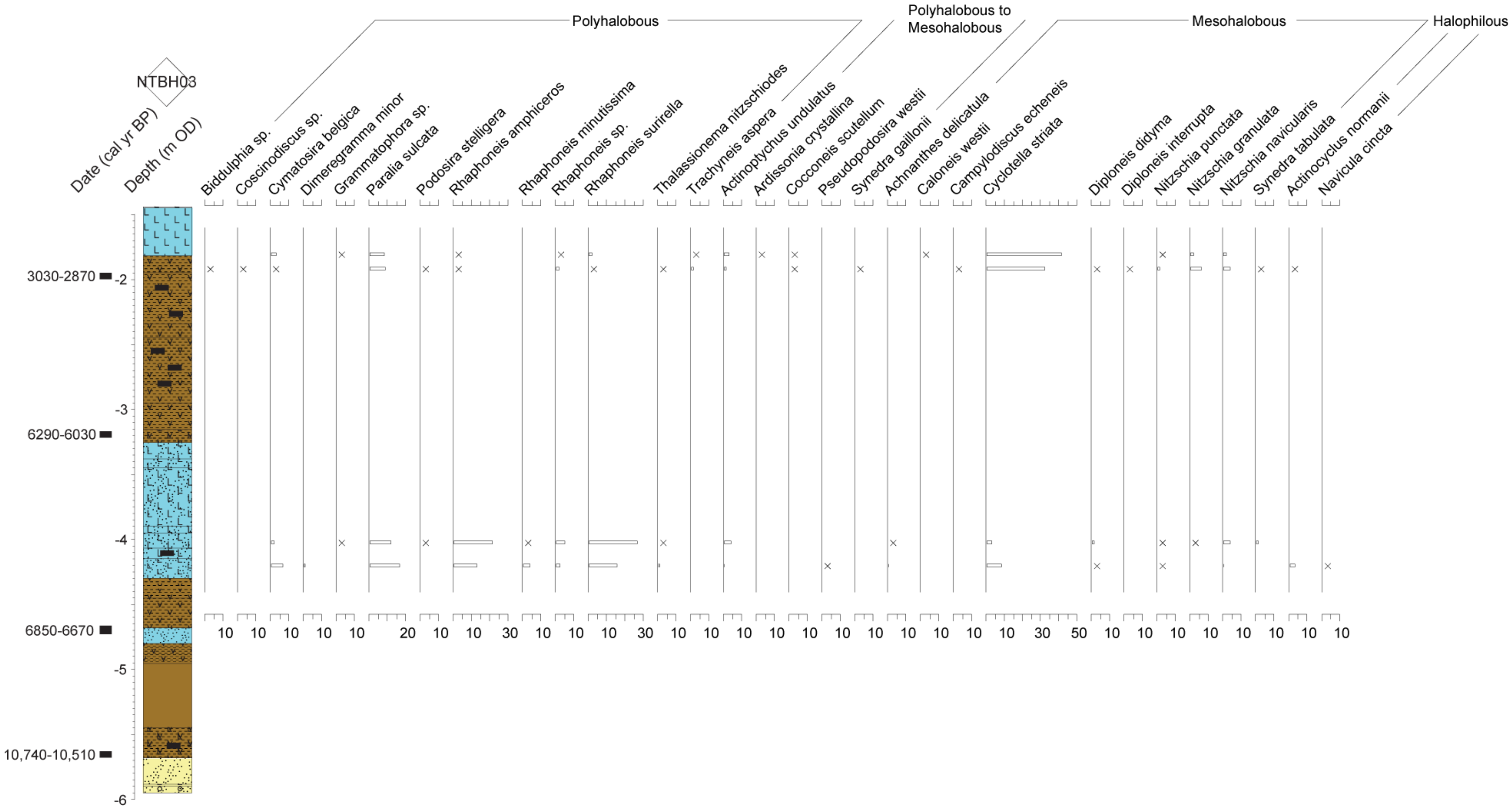


Figure 9: Diatom percentage diagram for borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

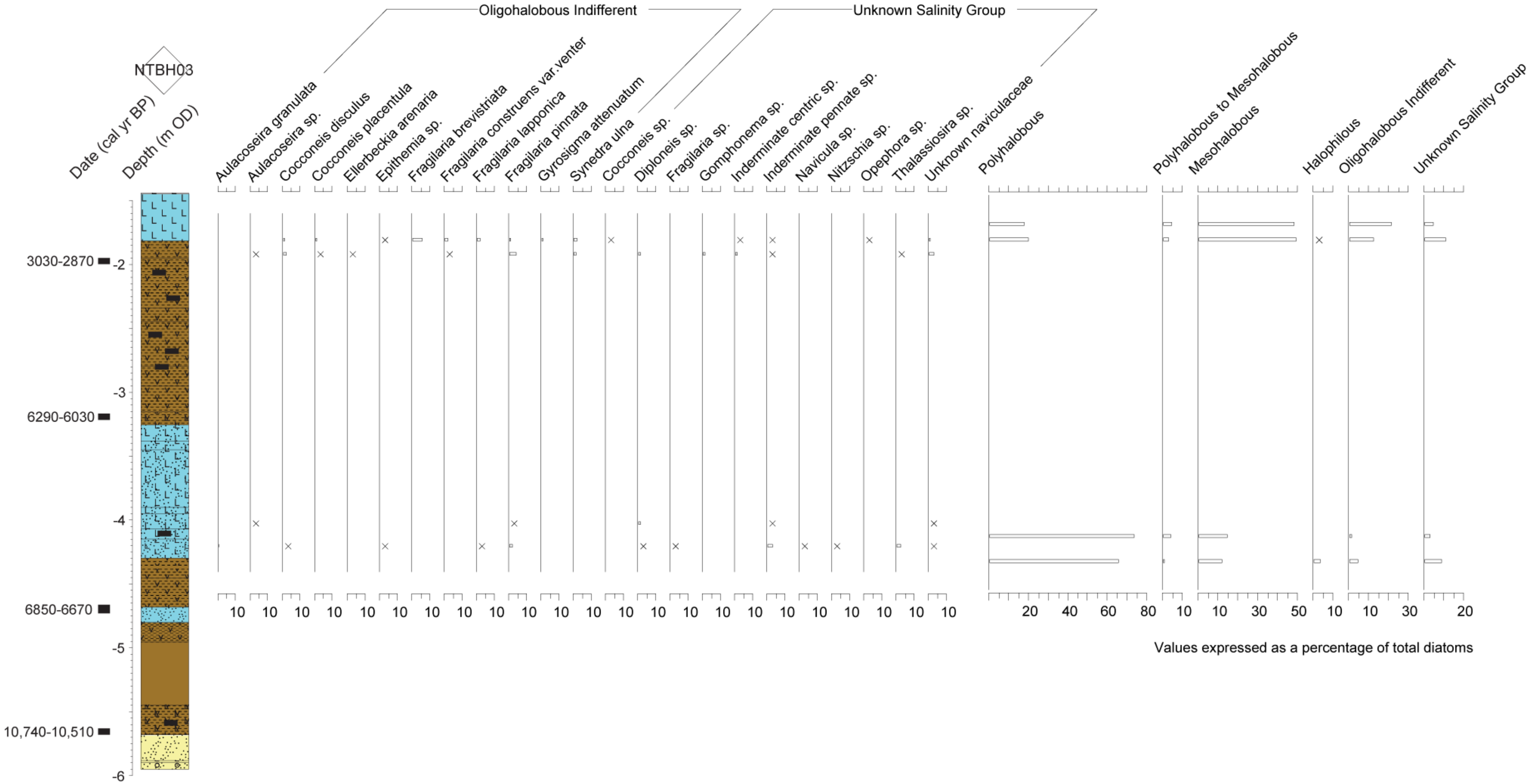


Figure 9: Diatom percentage diagram for borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Table 7: Results of the <SSBH1C> detailed diatom assessment, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Diatom Taxon/ Sample Depth (m) OD	-0.56 to -0.57	-0.68 to -0.69	-0.82 to -0.83	-2.40 to -2.41	-2.50 to -2.51	-2.59 to -2.60	-2.68 to -2.69	-2.80 to -2.81	-2.92 to -2.93	-3.02 to -3.03
Polyhalobous										
Paralia sulcata			1							
Rhaphoneis amphiceros/surirella										1
Polyhalobous to Mesohalobous										
Pseudopodosira westii			cf							
Mesohalobous										
Cyclotella striata										1
Nitzschia navicularis		2	2		1	cf				
Oligohalobous Indifferent										
Synedra ulna										1
Unknown Salinity Group										
Inderminate centric sp.			1		1					
Inderminate pennate sp.										1
Unknown diatom fragment		1	1							1
Unknown naviculaceae			1							

RESULTS OF THE WATERLOGGED PLANT MACROFOSSIL ANALYSIS (SEEDS AND WOOD)

The results of the borehole <SSBH1C> and <NTBH03> waterlogged macrofossil (seeds and wood) analysis are displayed in Tables 8 and 9.

Results and interpretation of the waterlogged seed analysis

Borehole <NTBH03>

The majority of the samples in borehole <NTBH03> are dominated by tree and shrub taxa including *Alnus glutinosa* (alder), *Sambucus nigra/racemosa* (elder), *Rubus* sp. (e.g. bramble), *Corylus avellana* (hazel) and cf. *Quercus robur/Corylus avellana* (oak/hazel). Herbaceous taxa are common throughout, including *Ranunculus repens* (creeping buttercup), *Lycopus europaeus* (gypsywort), *Rumex/Polygonum* sp. (dock/sorrel/knotweed), Apiaceae (carrot family), cf *Juncus* sp. (rush), *Solanum* sp. (nightshade) and indeterminate Poaceae (grass family). The aquatic taxon *Sparganium erectum* (bur-reed) is present in the uppermost sample (-1.86 to -1.95m OD). The assemblage in borehole <NTBH03> is thus indicative of a fen carr dominated by alder and hazel with an understorey of elder, bramble and herbaceous taxa. Standing water is indicated by the presence of bur-reed in the uppermost sample (-1.86 to -1.95m OD). A notable exception is the lowermost sample in the sequence (-5.63 to -5.68m OD), dominated entirely by the herbaceous taxa *Rumex* or *Polygonum* sp. (dock/sorrel/knotweed).

Borehole <SSBH1C>

The assemblage through the sequence in borehole <SSBH1C> is dominated by tree and shrub taxa including *Alnus glutinosa* (alder), *Corylus avellana* (hazel), *Rubus* sp. (e.g. bramble) and *Sambucus nigra/racemosa* (elder). Herbaceous taxa were present and included *Ranunculus* cf. *repens* (cf. creeping buttercup), *Polygonum* sp. (knotweed), *Lycopus europaeus* (gypsywort), *Solanum* sp. (nightshade) and cf. *Carex* sp. (sedge). Below ca. -1.33m OD the assemblage is composed entirely of alder, hazel, bramble, creeping buttercup and knotweed, indicative of a fen carr dominated by alder with an understorey of bramble and herbaceous taxa. There is some evidence for wetter conditions above *ca*. -1.33m OD, indicated by the presence of bur-reed (often found growing in permanent shallow water) and gypsywort (found in marshes and fens or by streams and ditches). *Solanum dulcamara* (nightshade) can be found in woody areas and in damp areas on the banks of swamps. The assemblage above *ca*. -1.33m OD is thus indicative of a fen carr dominated by alder with an understorey of bramble, herbaceous and aquatic taxa growing in or near permanent standing water.

Results and interpretation of the waterlogged wood analysis

Of the 342 fragments examined across both boreholes <NTBH03> (Table 8) and <SSBH1C> (Table 9) 220 were identified as *Alnus glutinosa* (alder), 13 fragments were identified as *Fraxinus excelsior* (ash), 1 fragment as *Salix*/*Poplus* sp. (willow/poplar) and 1 fragment as *Corylus avellana* (hazel). The majority of the wood identified derived from either twig wood or round wood from small branches. The remaining fragments, including bark fragments, could not be identified and were recorded as indeterminate (107 fragments). No identifiable wood fragments were recorded from the basal organic-rich sediment in borehole <NTBH03>.

The contents of the samples examined are suggestive of accumulated natural debris, comprising bark, twigs and small branches in the location of both boreholes. Alder was consistently the most abundant taxon identified which suggests that it was the principle source of woody debris throughout the period represented by the deposits. The abundance of alder suggests the presence of alder woodland, alongside other taxa tolerant of, or favouring wet soil; in this instance the occasional presence of ash, willow/poplar and hazel. The quality of preservation was generally good. Bark fragments were noticeably larger, and more robust, than twig and round wood fragments – most of which were small and more fragile. Almost all of the wood examined, and the 3 fragments of charcoal, contained fungal hyphae, in some instances in considerable quantities, suggesting prolonged decay at the time of burial.

Table 8: Results of the waterlogged plant macrofossil (seeds) assessment of borehole <NTBH03>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Volume (ml)	Waterlogged seeds			Waterlogged wood			
		Latin name	**Common name**	**Quantity**	**Latin name**	**Common name**	**Quantity**	**Comments**
-1.86 to -1.95	1100	*Rubus sp.* *Sambucus nigra/racemosa* *Ranunculus repens* *Sparganium erectum* *Lycopus europaeus* *Unidentified*	e.g. bramble elder creeping buttercup bur reed gypsywort -	3 6 6 2 2 2	*Alnus glutinosa*	-	10	-
-1.95 to -2.00	300	*Sambucus nigra/racemosa*	elder	1	*Alnus glutinosa* **(C14)** Indeterminate	alder -	4 1	Including x1 & twigwood *ca*. 3 years old x4 Bark
-2.00 to -2.15	800	*Rubus sp.* *Ranunculus repens* *Sambucus nigra/racemosa* *cf. Juncus sp.*	e.g. bramble creeping buttercup elder rush	17 2 1 1	*Alnus glutinosa* Indeterminate	alder -	7 3	x3 bark fragments
-2.15 to -2.25	600	*Rubus* sp.	e.g. bramble	1	*Fraxinus excelsior* Indeterminate	ash -	2 8	- Hardwood, x4 bark fragments
-2.25 to -2.34	600	-	-	-	*Alnus glutinosa* Indeterminate	alder -	3 7	- x3 bark fragments
-2.34 to -2.45	700	-	-	-	*Alnus glutinosa* cf *Fraxinus excelsior* Indeterminate	alder ash -	1 3 6	- - x6 bark fragments
-2.45 to -2.53	250	-	-	-	-	-	-	-
-2.56 to -2.63	400	*Alnus glutinosa* *Rubus* sp. Apiaceae	alder e.g. bramble carrot family	3 1 2	-	-	-	-
-2.63 to -2.72	600	*Rubus sp.*	e.g. bramble	5	*Alnus glutinosa* Indeterminate	alder -	8 2	- x2 bark fragments
-2.72 to -2.80	400	-	-	-	*Alnus glutinosa* Indeterminate	alder -	5 5	- x10 bark fragments.
-2.82 to -2.92	1050	-	-	-	*Alnus glutinosa*	alder	10	-
-2.98 to -3.08	550	*Lycopus europaeus* *Alnus glutinosa* catkin *Alnus glutinosa* fruit *Corylus avellana* nut shell	gypsywort alder alder hazel (fragments)	1 44 3 34	*Alnus glutinosa* cf *Fraxinus excelsior*	alder ash	9 1	- -

		Sambucus nigra/racemosa *Rubus* sp. *Rumex/Polygonum* sp. cf. *Ranunculus repens*	elder e.g. bramble dock/sorrel/knotweed creeping buttercup	2 9 4 2				
-3.08 to -3.18	800	*Alnus glutinosa catkin* *cf. Quercus robur/Corylus avellana* nut shell (fragments) *Rubus sp.* *Solanum sp.*	alder oak/hazel bramble nightshade	21 12 3 1	*Alnus glutinosa* Indeterminate	alder -	9 1	
-3.18 to -3.28	500	*Alnus glutinosa* catkin *Alnus glutinosa* fruit cf. *Corylus avellana* nut	alder alder hazel	11 2 1	*Alnus glutinosa* Indeterminate	alder	4 6	- x6 bark fragments.
-4.24 to -4.31	900	*Alnus glutinosa catkin* *Ranunculus repens* *cf. Poaceae* *Lycopus europaeus* Unidentified	Alder creeping buttercup grass family gypsywort -	18 6 1 1 1	*Alnus glutinosa* Indeterminate	alder -	7 3	- x3 bark fragments
-4.31 to -4.45	125	*Ranunculus repens*	creeping buttercup	2	*Alnus glutinosa* Indeterminate	alder	5 5	- x5 bark fragments
-4.68 to -4.76	200	*Lycopus* sp. Unidentifiable (fragment)	gypsywort -	1 1	*Alnus glutinosa* Indeterminate	alder -	2 3	x3 bark fragments
-4.80 to -4.95	1300	*cf. Apiaceae* *cf. Juncus sp.*	carrot family rush	2 1	-	-	-	-
-5.53 to -5.62	400	*Alnus glutinosa* catkin *Alnus glutinosa* fruit *Rumex/Polygonum* sp. *Ranunculus* cf. *repens* *Lycopus europaeus* Apiaceae Unidentifiable (fragments)	alder alder dock/sorrel/knotweed creeping buttercup gypsywort carrot family -	9 6 18 1 15 1 3	-	-	-	-
-5.63 to -5.68	200	*Rumex/Polygonum* sp. **(C14)**	dock/sorrel/knotweed	15	Indeterminate	-	5	

Table 9: Results of the waterlogged plant macrofossil (seeds and wood) assessment of borehole <SSBH1C>, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Volume (ml)	Waterlogged seeds			Waterlogged wood			
		Latin name	**Common name**	**Quantity**	**Latin name**	**Common name**	**Quantity**	**Comments**
-0.78 to -0.88	550	-	-		*Alnus glutinosa*	alder	10	Including x1 twig: *ca*. 2 years; *ca*. 3mm diameter
-0.88 to -0.98	1100	*Rubus* sp. *Sambucus nigra/racemosa* *Alnus glutinosa* catkin *Ranunculus repens* *Lycopus europaeus* *Sparganium erectum* Unidentified	bramble elder alder creeping buttercup gypsywort bur reed -	1 2 8 4 4 1 1	*Alnus glutinosa*	alder	10	-
-0.98 to -1.03	100	*Rubus* sp. *Ranunculus* cf. *repens* *Alnus glutinosa* Unidentified	e.g. bramble creeping buttercup alder -	1 3 6 1	*Alnus glutinosa* **(C14)** Indeterminate	alder -	3 2	- Bark
-1.03 to -1.09	300	None	-		*Alnus glutinosa*	alder	10	-
-1.09 to -1.14	400	Unidentified	-	1	*Alnus glutinosa* Indeterminate	alder -	9 1	- x1 bark fragment
-1.14 to -1.24	500	*Rubus* sp. *Alnus glutinosa* catkin *Corylus avellana* nut shell (fragments)	e.g. bramble alder hazel	1 8 3	*Alnus glutinosa* <u>Charcoal fragments</u> *Alnus glutinosa* cf *Fraxinus excelsior*	alder alder ash	10 2 1	- - -
-1.24 to -1.33	950	*Alnus glutinosa* catkin *Rubus* sp. cf. *Corylus avellana* *Polygonum* sp. *Lycopus europaeus* *Solanum* sp. cf. *Carex* sp. Unidentified	alder bramble hazel knotweed gypsywort nightshade sedge -	31 1 1 1 2 1 1 1	*Alnus glutinosa* *Corylus avellana* Indeterminate		5 1 4	- - x4 bark fragments
-1.33 to -1.48	1200	*Alnus glutinosa* fruit *Alnus glutinosa* catkin	alder alder	10 19	*Alnus glutinosa*	alder	10	-
-1.48 to -1.60	450	*Alnus glutinosa* catkin *Ranunculus* cf. *repens*	alder cf. creeping buttercup	9 1	*Alnus glutinosa* cf *Salix/Populus* sp. Indeterminate	alder willow/poplar -	4 1 5	- - x5 bark fragments.

		Unidentified	-	1				
-1.60 to -1.70	800	-	-	-	*Alnus glutinosa* cf *Fraxinus excelsior* Indeterminate	alder ash -	2 2 6	- - including x1 bark fragment
-1.70 to -1.82	600	-	-		*Alnus glutinosa* Indeterminate	alder -	5 5	- x1 hardwood, x3 bark fragments.
-1.82 to -1.98	1400	*Rubus* sp. *Ranunculus* cf. *repens*	bramble creeping buttercup	7 1	*Alnus glutinosa* *Fraxinus excelsior* Indeterminate	alder ash -	2 1 7	- - x5 bark fragments
-2.01 to -2.08	500	*Rubus* sp. *Alnus glutinosa* fruit *Alnus glutinosa* catkin *Ranunculus* cf. *repens* *Polygonum sp.*	e.g. bramble alder alder cf. creeping buttercup knotweed	1 1 1 1 1	*Alnus glutinosa* Indeterminate	alder -	8 2	Including x4 twig wood. x2 bark fragments.
-2.09 to -2.15	500	*Alnus glutinosa* catkin	alder	2	*Alnus glutinosa*	alder	10	-
-2.15 to -2.22	550	*Rubus* sp.	e.g. bramble	1	Indeterminate	-	10	x10 bark fragments.
-2.26 to -2.32	200	*Corylus avellana* nut shell (fragment)	hazel	1	*Alnus glutinosa*	alder	5	-
-2.32 to -2.41	800	*Rubus* sp.	bramble	1	*Alnus glutinosa*	alder	10	-
-2.41 to -2.48	800	*Alnus glutinosa* catkin	alder	2	*Alnus glutinosa*	alder	10	-
-2.50 to -2.56	350	*Alnus glutinosa* catkin *Ranunculus* cf. *repens*	alder cf. creeping buttercup	2 1	*Alnus glutinosa* *Fraxinus excelsior* Indeterminate	alder ash -	3 2 5	Including. x1 twig: *ca*. 3 years; *ca*. 8mm diameter. Very narrow growth rings (7+). x1 hardwood, x4 bark fragments.
-2.58 to -2.66	800	*Alnus glutinosa* catkin	alder	2	*Alnus glutinosa* Indeterminate	alder -	5 5	- x5 bark fragments
-2.75 to -2.85	700	*Rubus* sp.	bramble	1	*Alnus glutinosa* *Fraxinus excelsior*	alder ash	9 1	- -
-3.01 to -3.06	200	-	-		*Alnus glutinosa* **(C14)**	alder	5	-

RESULTS AND INTERPRETATION OF THE INSECT ANALYSIS

<NTBH03>

Following extraction and rapid assessment, insect remains were recorded in only three samples (Table 11).

-1.86 to -1.95m OD

This sample yielded only one identifiable species, the rove beetle *Lesteva longelytrata* which lives in wet mosses by streams and in bogs.

-2.54 to -2.34m OD

This sample yielded five identifiable taxa. The only water beetle is *Hydraena britteni*. This beetle lives in both running and standing water with grasses and mosses. The other specimens could only be identified to the genus level. The ground beetle genus *Trechus* includes species that live in damp habitats, dry open ground, and meadows. The rove beetle genus *Olophrum* includes species that live in damp habitats, leaf litter, mosses, and various riparian habitats. The rove beetle genus *Atheta* includes species that live in damp to wet leaf litter. Species of the dung beetle genus *Aphodius* mostly feed on herbivore dung.

-3.08 to -3.17m OD

This sample yielded two rove beetle specimens that could only be identified to the genus level. The rove beetle genus *Olophrum* includes species that live in damp habitats, leaf litter, mosses, and various riparian habitats. Many species of the rove beetle genus *Tachinus* live in rotting vegetation or fungi.

<SSBH1C>

Following extraction and rapid assessment, insect remains were recorded in eight samples (Table 10).

-0.88 to -0.98m OD

This sample contained just two identified taxa, the water scavenger beetle *Hydraena britteni* and the riparian rove beetle *Stenus*. The former lives in grassy streams in fens and bogs. The latter is a group of beetles that live along the margins of running and standing water.

-1.24 to -1.33m OD

The aquatic element of this small faunal assemblage includes three taxa: the water scavenger beetles *Cercyon* and *Hydraena britteni*. Most species of *Cercyon* live in shallow standing water with rich aquatic vegetation. *Hydraena britenni* lives in both running and standing water with grasses and mosses. The aquatic leaf beetles in the genus *Plateumaris* mostly live in shallow water reed swamp environments. The rove beetles *Arpedium quadrum* and *Lesteva longelytrata* both live in wet vegetation. The former is found in swamps and damp leaf litter and the latter live in wet mosses by streams and in bogs. The riparian rove beetle *Stenus* is a group of beetles that live along the margins of running and standing water. *Lesteva longelytrata* lives in wet mosses by streams and in bogs. The weevil *Kissophagus hederae* feeds under the bark of *Hedera* (ivy) and has been found in alder carr habitats. The other two taxa are both associated with dung and rotting vegetation. These include the rove beetle *Oxytelus sculptus* and the dung beetle *Aphodius*. Many species of *Aphodius* feed on herbivore dung.

<u>-1.33 to -1.48m OD</u>

This sample contained just five identified taxa. The water scavenger beetle *Hydraena britteni* lives in grassy streams in fens and bogs. *Lesteva longelytrata* is a rove beetle that lives in wet mosses by streams and in bogs. Most species of the rove beetle genus *Atheta* live in damp to wet leaf litter. The riparian rove beetle *Stenus* is a group of beetles that live along the margins of running and standing water. The bark beetle *Leperisinus fraxini*, as the name implies, lives under the bark of ash trees.

<u>-1.82 to -1.91m OD</u>

This sample yielded only one identifiable insect, the water scavenger beetle *Coelostma orbiculare*. This species lives in well vegetated standing water in fens and marshes. The only other fossil identified was the remains of the water flea *Daphnia*. These live in pools, ponds and lakes.

<u>-2.30 to -2.41m OD</u>

The only taxon identified from this sample is the water scavenger beetle *Hydraena riparia*. This species lives in both running and standing water where there is rich vegetation.

<u>-2.41 to -2.48m OD</u>

This sample yielded only two identifiable species, the water scavenger beetle *Hydraena britteni* and the weevil *Tachyerges stigma*. The former lives in grassy streams in fens and bogs. The latter is found on the banks of swamps, fens and bogs, where it feeds on hazel, birch, and willows.

<u>-2.58 to -2.66m OD</u>

This sample yielded only one identifiable species, the ground beetle *Pterostichus minor*. This predator is found in damp habitats, such as marshes, bogs and fens.

Table 10: Results of the insect analysis, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

	<NTBH03>				<SSBH1C>							
Depth (m OD)	-1.86 to -1.95	-2.54 to -2.34	-2.82 to -2.95	-3.08 to -3.17	-1.24 to -1.33	-0.88 to -0.98	-1.24 to -1.33	-1.33 to -1.48	-1.82 to -1.91	-2.30 to -2.41	-2.41 to -2.48	-2.58 to -2.66
COLEOPTERA												
Carabidae												
Trechus sp.		1										
Pterostichus minor (Gyll.)												1
Hydrophilidae												
Coelostma orbiculare F.									1			
Cercyon sp.					1							
Hydraenidae												
Hydraena britteni Joy		1			1	1	1	1			1	
*Hydraena riparia*Kug.										1		
Staphylinidae												
Arpedium quadrum (Grav.)					1							
Lesteva longelytrata (Goeze)	1				2		1	1				
Olophrum sp.		1		1								
Tachinus sp.				1								
Oxytelus sculptus Grav.					1							
Atheta sp.		1						1				
Stenus spp.					1	1	1	2				
Scarabaeidae												
Aphodius sp.		2			1							
Chrysomelidae												
Plateumaris sp.					1							
Curculionidae												
Tachyerges stigma (Germ.)											1	

Kissophagus hederae (Schmitt)							1					
Leperisinus cf. fraxini (Panz._								1				
HEMIPTERA												
Lygaeidae												
Genus et sp. Indet					1							
TRICHOPERA												
Limnephilidae												
Genus et sp indet					1							
HYMENOPTERA												
Formicidae												
Gen et sp indet					1							
CRUSTACEA												
Daphnia sp.									1			

DISCUSSION

Landscape evolution

Several distinct phases of landscape evolution can be recognised along the Cable Car route during Late Glacial and Holocene times. At the base of the sequence overlying the London Clay, a thick unit of sand and gravel is recorded across the site representative of a high energy braided river system (the Shepperton Gravel), laid down on the valley floor of the River Thames at the end of the Late Glacial period (Marine Isotope Stage 2, Late Devensian, *ca*. 16,000 to 11,500 cal BP). The valley floor was characterised by longitudinal gravel bars separated by channels in which some finer grained deposition of sand and silt had also taken place (Bridgland *et al*., 1995; Gibbard, 1994, 1995). The relief on this surface is generally around 2-3m and across much of the southern side of the River Thames on the Cable Car route lies uniformly between -2.25m and -3.45m OD. In the centre of the River Thames, this surface rather unsurprisingly decreases to below -10m OD; however, on the north bank of the river, the gravel surface is more variable generally ranging between -2.5m and nearly -6.00m OD. These variations are arranged such as to suggest a topographic high point (gravel 'eyot'), broadly comparable to that of the Bermondsey and Horseleydown gravel 'highs' (eyots) in the area of the North Intermediate Tower. This gravel island appears to continue to the west, with a similar height of -2.5m recorded within Wilkinson *et al*'s (2000) borehole at West Silvertown. In addition, investigations even further west (see Figure 1) at the Royal Docks Community School (Holder, 1988) and Royal Albert Dock (Batchelor, 2009) indicate a gravel surface above -2.5m OD, whilst to the north and south of these sites, the Gravel surface decreases to between -3.5m OD (e.g. Golfers Driving Range; Batchelor, 2009) and -5.0m OD (e.g. North Woolwich Pumping Station; Sidell, 2003). The sequence from borehole <NTBH03> therefore appears to represent a sequence from a deep channel which borders a gravel high point.

During the Early Holocene, the main course of the River Thames probably began to be confined to a single meandering channel, and the surface of the Shepperton Gravel was progressively buried beneath Alluvium or Peat under the influence of generally rising relative sea level. Sedimentation largely occurred earliest within deeper areas of the Shepperton Gravel, and migrated upwards and outwards. Therefore, the earliest record of Holocene sediment is in borehole <NTBH03> where accumulation began above -5.88m OD (sometime before 10,740-10,510 cal BP). However, this date is between *ca*. 1000 and 2000 years later than accumulation began at West Silvertown (12,800-11,690 cal BP; Wilkinson *et al*., 2000), an occurrence which is not entirely understood, since accumulation at West Silvertown began at a much higher elevation than in <NTBH03>, and the vegetation history suggested by the new record is analogous to it and sequences such as Bramcote Green (Thomas and

Rackham, 1996). One possible explanation is that the sediment recorded at the base of the <NTBH03> is not entirely *in situ*, having been derived from further upstream, or from the banks of the channel. However, this explanation also seems floored as the pollen assemblage is in stratigraphic order. This conundrum is only likely to be solved by additional radiocarbon dates.

Above this, in borehole <NTBH03>, tufa-rich sand deposits accumulated prior to a brief period of semi-terrestrial peat accumulation and renewal of inorganic sedimentation. This horizon of Peat was dated to 6850-6670 cal BP, which once again seems unlikely since the pollen assemblage indicates the dominance of pine woodland just prior to this, which at West Silvertown was an event dated between 12,080-11230 and 11,035-10,290 cal BP. It is possible therefore that there is a hiatus before and after deposition of the tufa-rich sands and peat accumulation; however, as with the lowermost radiocarbon determination, it is likely that only additional radiocarbon dates can provide clarification. Within these lowermost units from borehole <NTBH03>, diatoms were unfortunately absent and thus the hydrological history is uncertain, but in the inorganic sediment that capped the first Peat horizon, pollen and diatom remains indicate an estuarine influence and the nearby growth of saline taxa.

In both boreholes analysed, the Shepperton Gravel and lower generally inorganic Alluvium is overlain by a thick horizon of Peat, representative of a transition to sediment accumulation in a semi-terrestrial environment. Across all the Cable Car boreholes, this horizon varied in thickness from 2.43m in borehole NTBH02 on the north side of the river to 0.92m in borehole B4 on the south side, with an average thickness of 1.60m. The combined programme of radiocarbon dating suggests that Peat formation probably commenced between 5000 and 6000 cal BP and continued until around 3000 cal BP. However, the date of initiation varied reflecting the surface of the underlying topography, and probably distance from the river. Unfortunately, there once again appears to be an unexplained radiocarbon dating discrepancy, this time in borehole <SSBH1C>. However, the initiation of peat accumulation in the Lower Thames Valley is generally attributed to hydrological changes consequent of continually rising sea level, and this is likely to also be the case within sequences along the Cable Car route. The archaeobotanical and zooarchaeological records also indicate that the peat formed in a largely freshwater environment, which is analogous to other sites in this area of the Lower Thames Valley at the time.

The cessation of Peat formation around 3000 cal BP was followed by the accumulation of the 'Upper Alluvium'. This date is analogous to other sites in the Lower Thames Valley, although the difference in elevation for the top of the peat between boreholes <SSBH1C> and

<NTBH03> is >1m. The cessation of peat formation is attributed to an increase in the rate of relative sea level rise which outstripped peat formation causing inundation. Archaeobotanical and zooarchaelogical remains provide strong evidence that the site came under estuarine influence at this time.

Vegetation history

As discussed above, the radiocarbon-dated palaeoenvironmental records from the London Cable Car are not entirely contemporaneous and thus do not contain the same record of vegetation history. Borehole <NTBH03> contains the longest record of vegetation history, spanning from at least 10,740-10,510 to 3030-2870 cal BP, which incorporates the Mesolithic to Bronze Age cultural periods. Borehole <SSBH1C> contains a shorter sequence from spanning from 5850-5310 to 3380-3210 cal BP, which equates to the Neolithic to Bronze Age cultural periods.

The radiocarbon dated palaeoenvironmental record from borehole <NTBH03> indicates that LPAZ BH3-1 can be equated to the Early Mesolithic, although radiocarbon dates from nearby West Silvertown would suggest an earlier Late Devensian date. During this period, grasses, sedges and other herbaceous taxa typical of grasslands dominated the wetland environment with birch and pine woodland either growing nearby, or as part of the regional vegetation. This assemblage is indicative of cold weather conditions, however, towards the latter half of the zone, increases in trees such as alder, lime and elm suggest a transition towards warmer conditions. Despite the difference in chronology, the new record shares two particular characteristics with the West Silvertown sequence: (1) the lack of juniper (*Juniperus*) pollen, and (2) the early occurrence of alder. *Juniperus* has been recorded in other Late Glacial deposits from the London region such as Bramcote Green (Thomas and Rackham, 1996) and Enfield Lock (Chambers *et al*., 1996). Scaife (in Wilkinson *et al*., 2000), suggest that this absence may be due to the rapid occurrence of pine within the Silvertown region. Similarly, in previous studies Lower Thames Valley pollen analytical studies (e.g. Devoy, 1979), alder is considered unlikely to have been growing within the region until at least 8500 BP. However, this now seems unlikely due to the occurrence of alder pollen and seeds in both <NTBH03> and at West Silvertown from shortly after 10,740-10,510 cal BP (Thomas and Rackham, 1996), together with the recording of earlier alder macrofossils at Bramcote Green and Ponders End in the Lea Valley (Godwin, 1964; Reid, 1916), as well as earlier occurrences recorded within other lowland wetland environments across southern England (e.g. Waller, 1993; 1998).

The transition to LPAZ BH3-2 is characterised by the dominance of pine, an occurrence not reflected in the plant macrofossil record, but can only be representative of onsite woodland. As discussed above, this peak was dated to 6850-6670 cal BP (Late Mesolithic/Early Neolithic), a date far later than the Early Holocene age recorded at West Silvertown (between 12,080-11230 and 11,035-10,290 cal BP) and other sites in London such as Bramcote Green (Thomas and Rackham, 1996) for this occurrence. Above this, the new archaeobotanical record indicates a transition towards alder and willow woodland dominating the floodplain vegetation cover with a range of brambles, grasses, sedges, ferns and aquatics. This assemblage of plants is indicative of a damp surface incorporating standing water habitats such (e.g. ponds). On the nearby dryland, mixed deciduous woodland and hazel shrubland dominated with lime and oak, and probably ash, elm, birch and pine. These warmth-loving trees, especially elm and lime, became established during a period of Early Holocene climatic amelioration, forming a mixed deciduous forest ecosystem. This forest would have been present throughout the Lower Thames Valley, and probably formed excellent areas for human occupation during the Mesolithic/Neolithic cultural periods, with rich plant and animal resources, including hazel nuts and acorns, and probably *Cervus elaphus* (red deer) and *Bos primigenius* (auroch) (see Thomas and Rackham, 1996; Sidell *et al.,* 2002).

LPAZ BH3-4 is approximately contemporaneous with LPAZ's BH1C-1 and 2. In both sequences, this equates to the main period of Peat accumulation which spans from between *ca*. 6000 to *ca*. 3000 cal BP (Neolithic to Bronze Age cultural periods). During this period, alder continued to dominate on the wetland, whilst mixed deciduous woodland grew on the dryland. However, this period incorporates three important events: (1) the decline of elm (recorded in the <NTBH03> sequence only; (2) the colonisation and decline of yew, and (3) a peak in lime values.

<u>The elm decline</u>

The radiocarbon-dated pollen-stratigraphical record from <NTBH03> indicates a pronounced decline in elm woodland at *ca.* 6290-6030 cal BP, whilst the sequence from <SSBH1C> post-dates the decline. This broadly synchronous, pan-European event was arguably the most significant change in woodland composition and structure during around this time, and started in the British Isles between *ca.* 6343 and 6307 cal yr BP (a period of 36 years), and ended between *ca.* 5420 and 5290 cal yr BP (Parker *et al*., 2002). The reasons for the decline of elm have been of great debate over the years with the following hypotheses made: (1) climate change to cooler conditions (e.g. Smith, 1981); (2) soil deterioration due to e.g. Mesolithic burning (Peglar and Birks, 1993), or waterlogging and peat formation (paludification; Waller, 1994a); (3) competitive exclusion (e.g. Huntley and Birks, 1983;

Peglar and Birks, 1993); (4) human interference with natural vegetation (e.g. Scaife, 1988; Lamb and Thompson, 2005), and (5) Dutch elm disease (e.g. Perry and Moore, 1987; Girling, 1988). The two most strongly argued causes for the decline are human interference with natural vegetation succession and Dutch elm disease, with a combination of the two, the most likely cause.

The argument for human activity centres on the fact that the decline in *Ulmus* pollen is contemporaneous with the transition from the Mesolithic to Neolithic cultural period and is often accompanied by palynological and/or coleopteran evidence for temporary episodes of clearance for cultivation and animal husbandry (e.g. Scaife, 1988; Wilkinson, 1988; Girling and Grieg, 1985). However, the evidence for a human caused decline is circumstantial with no definitive archaeological proof for the exploitation of *Ulmus* (Garbett, 1981; Rasmussen, 1989a,b), and arguments that the human population at this time would have been too small to cause a long-term reduction in woodland (e.g. Moe and Rackham, 1992).

Elm disease is caused by the fungus *Ophiostoma* (*Ceratocystis*) *ulmi* which is carried by the beetle *Scolytus scolytus*. The discovery of these insects at or near to a decline in elm pollen at sites such as Hampstead Heath (Girling, 1988; Girling and Grieg, 1985) and Red Moss of Candyglirach near Aberdeen (Clark and Edwards, 2004) is widely regarded as strong indication that disease was the main cause of the Neolithic elm decline. Further support for this hypothesis has been provided by the discovery of microscopic anatomical features in elm wood analogous to those found in modern diseased trees (Rasmussen and Christensen, 1997), and by rapid, large-scale declines in elm in both recent and Middle Holocene pollen-stratigraphic records (Perry and Moore, 1987; Peglar and Birks, 1993). However, despite the support for this hypothesis conclusive evidence for a disease-caused Holocene decline remains absent.

It is for this reason that the elm decline is considered most likely to have been caused by the interaction of human activity and disease. Whether farming facilitated the spread of the disease by creating opportunities for its easier transmission through woodland (for example the pollarding of elm branches would have produced cuts within the tree, reducing its natural defences, and allowing the direct attack of insects; Austin, pers comm.), or whether disease created woodland glades suitable for cultivation, or pastoralism, may have varied spatially.

The latest evidence from the Lower Thames Valley are two new records of the presence of *Scolytus scolytus* at Horton Kirby and Old Seager Distillery (Batchelor *et al*., in prep). Both sites also contain elm pollen and waterlogged wood, whilst the latter site contains flint artefacts. These are unique sites, and when combined with other sites in the Lower Thames Valley, suggest that human activity was the initial factor allowing the spread of disease (Batchelor *et al.*, in prep). However, within the <NTBH03> sequence, the decline coincides with peat accumulation, and thus at this site it is more likely to be paludification (the expansion of wetland; Waller, 1994a) that caused the decline of elm. The expansion of wetland onto areas of former dry ground causing the retreat of elm away from the site of deposition.

<u>The colonisation and decline of yew</u>

The pollen-stratigraphic records indicate that yew became a component of the alder dominated wetland woodland in the nearby vicinity of both boreholes after the elm decline. At both sites, the concentration of pollen is low, and no waterlogged wood was recorded. However, there are a number of species specific factors that may result in a limited pollen concentration despite its onsite or nearby growth. Firstly, there is some debate as to the relationship between yew pollen values and the quantity of trees they represent (e.g. Andersen, 1970, 1973, 1975; Bradshaw, 1981; Mitchell, 1988). Secondly the tree does not reach sexual maturity until it is 70 years of age; therefore the expansion of yew within the new pollen-stratigraphic record will lag behind its colonisation of the floodplain, and its presence will go undetected if it dies before this time, as at some sites (e.g. Seel, 2001). Thirdly, the tree is dioecious, and therefore its presence may go completely unrecorded (Thomas and Polwart, 2003). However, several other sites have also demonstrated the growth of yew-alder dominated woodland at this time in the Lower Thames Valley (e.g. Seel, 2001, Branch *et al.,* in prep, Batchelor, 2009), as well as elsewhere in the British Isles (Godwin, 1940; Waller, 1994b), Ireland (Mitchell, 1990) and continental Europe (Deforce and Bastiaens, 2007). In particular, yew wood and high pollen concentration have been recorded at a number of sites in the Newham area, although the recording of pollen at <SSBH1C> represents a new finding from this area of the Lower Thames Valley.

The growth of yew on peat at this time is important for two reasons:

1. *Palaeoecology*. The modern day ecology of yew is for dry and basic conditions such as chalk downland and limestone geology (Thomas and Polwart, 2003). Its occurrence on peat during the Middle Holocene is therefore somewhat surprising.
2. *Culture.* Yew is of great cultural significance and has been utilised from the Palaeolithic through to the modern day. The prehistoric importance of yew is demonstrated by its use in: (i) creating weapons and tools such as spears, swords, bows, knives and musical pipes (e.g. Clark, 1963; Coles *et al.*, 1978; Gowen, 2004, Sheridan, 2005), and (ii) constructing trackways, platforms and boats (Coles and Hibbert, 1968; Coles *et al.*, 1978;

Wright *et al.*, 1965, 2001).

Recent investigations aimed at increasing our knowledge and understanding of the palaeoecology of yew indicate that it colonised and declined from the wetland surface between 5000 and 4000 cal BP, with very few occurrences of pollen or waterlogged wood being recorded outside this time-frame (Batchelor, 2009). This frequent occurrence is therefore another reason why the radiocarbon date from the base of the Peat in borehole <SSBH1C> is considered to be incorrect. These same investigations also indicate that a dry peat surface was almost certainly required to enable the growth of yew on the Lower Thames Valley peat surface, however, more favourable climatic conditions, and likely areas of human disturbance may have influenced the colonisation of yew on the peat surface. The decline of yew was often related to wetter peat surface conditions, most likely caused by continually rising RSL. It was also considered likely that human activity had a far greater influence on the decline of yew, than on its expansion; it is notable that the decline occurs at the transition from the Neolithic to Bronze Age. A return towards a more continental climate may also have contributed to the yew decline from the wetland (Batchelor, 2009).

The new records from the Cable Car project largely support the existing model. The initial expansion of yew occurred at a time when the other lithostratigraphic and bioarchaeological records indicate a transition towards drier conditions, and a more mature wetland woodland community. Similarly, a decline in organic matter content contemporaneous with the fall in *Taxus* pollen values suggests increased inundation may have led to the departure of yew from the floodplain surface. There are no indicators to suggest that human activity may have caused the decline of yew at either site.

<u>The expansion of lime</u>

An unusual feature of both the new pollen-stratigraphic diagram is the increase of *Tilia* (lime) percentage values towards the top of zones LPAZ BH3-4 and LPAZ BH1C-1. Unlike most arboreal taxa, the pollen from lime is entomophilous (insect pollinated), and thus does not travel far from source. Therefore the high concentrations of lime suggest that it was growing nearby on areas of dryland at both sites at around the same time. Further radiocarbon dating would allow these periods of change to be identified.

The uppermost pollen assemblages from both boreholes <NTBH03> and <SSBH1C> are also approximately contemporaneous. Within both sequences it is difficult to establish the precise history since pollen concentration and preservation is poor. In both boreholes alder dominated woodland began to decline from the wetland, and in borehole <SSBH1C> was replaced by vegetation indicative of wetter conditions and estuarine inundation. The transition to these zones is also marked by a decrease in dryland woodland pollen taxa (e.g. *Quercus* and *Tilia*). The decline in woodland on the wetland and dryland is therefore approximately contemporaneous. This occurrence is analogous with many other sites across the Lower Thames Valley. Problems related to the taphonomy of pollen from wetland and dryland environments all inhibit the interpretation of pollen data, and our ability to confidently reconstruct vegetation succession and causes of environmental change on dryland, however, the occurrence of an array of herbaceous pollen taxa including cf *Cereale* type, Centaurea nigra which most likely originate from the dryland, with other taxa such as Poaceae, *Chenopodium* type, Lactuceae and *Sinapis* type may originate from a number of different environments, including the dryland, suggesting Bronze Age land clearance for settlement and/or farming purposes was taking place at this time.

However, the contemporaneous nature of the decline in woodland on both the wetland and dryland is striking and suggests a strong link between the two environments and possible causes. Indeed, it is considered probable that the increased rate of relative sea level (RSL) rise that brought about environmental change on the wetland, also contributed to the decline of mixed deciduous woodland on the dryland in two different ways. Firstly, RSL rise may have caused the expansion of wetland onto areas of former dryland, and/or the saturation of dryland soils. This would have caused the retreat of dryland woodland away from the sampling point. Secondly, the wetter conditions and estuarine inundation that caused the eventual abandonment of the wetland by Bronze Age people, most likely led to the concentration of anthropogenic activity (and thus clearance) on the neighbouring dryland edge. There seems little doubt that these RSL driven processes could have influenced the rate of woodland decline on the dryland; however, the precise temporal and spatial relationships between RSL change, soil deterioration, human activity and dryland woodland decline remain very difficult to measure.

CONCLUSIONS

The aim of this analysis report was to carry out a fuller investigation of the local and regional environments of the Holocene Peat and Alluvium, in order to permit a detailed reconstruction of spatial and temporal changes in the local environment, and to allow quantification of the relationships between vegetation succession, relative sea-level change, climate change and human activity in this area of the Lower Thames Valley. The main findings of the analysis are as follows:

1. The environmental archaeological investigation of the Cable Car site has enhanced knowledge and understanding of the environmental history of this part of the Lower Thames Valley.
2. The pre-Holocene topography of the Cable Car site and the sequence of Holocene sedimentation reflect conditions that are widely recorded in the valley of the estuarine Thames. The numerous boreholes put down within the site make possible a reasonably reliable reconstruction of the main features of the sub-surface topography and of the sequence of Holocene sedimentation.
3. The combined sedimentological (geoarchaeological) records indicate that during the Early to Middle Holocene, the undulating surface of the 'Shepperton Gravel' was progressively buried beneath Alluvium and Peat deposits of the River Thames. The main period of peat formation around 6000 cal yr BP resulting from continued postglacial sea level rise (see Devoy, 1979). Peat formation continued until sometime around *ca.* 3000 cal BP. This surface was overlain by an Upper Alluvium of estuarine origin, and probably reflects a rise in the rate of relative sea level rise. The peat recorded at the Cable Car site is undoubtedly part of the same biogenic sequence, the Tilbury III stage of Devoy's scheme.
4. The results of the analysis indicate large similarities in the archaeobotanical record between the <NTBH03> sequence and that previously recorded at West Silvertown. However, there are some large differences in the height and date at which various sediments/vegetation changes were recorded.
5. The biostratigraphical (zooarchaeological and archaeobotanical) records indicate that during the period of peat formation, there were specific important changes in both the wetland and dryland vegetation cover. Firstly, the decline of elm woodland, secondly the colonisation and decline of yew woodland, and thirdly and apparent expansion of lime woodland.
6. No definitive indications of human activity were recorded on the site, but the following aspects were noted as potentially significant: (1) the presence of a topographic high towards the north west of borehole <NTBH03>, which may have been suitable for human activity, and (2) changes in the vegetation composition on the dryland around the time of peat inundation (*ca.* 3000 cal yr BP).

RECOMMENDATIONS

It is recommended that following the results of the palaeoenvironmental analysis, further radiocarbon dating is carried out from select locations in both boreholes as a consequence of some of the anomalous results thus far recorded. These should be targeted on the following from borehole <NTBH03>: one date from the basal sediments to clarify the determination of

10,740-10,510 cal BP; one determination on the peak in *Pinus* pollen to clarify its age; one date from the top of the lower Peat (highest organic matter content) to clarify its age, and one determination on the peak in lime pollen towards the top of LPAZ BH3-4. From borehole <SSBH1C>, determinations should be made on the peak in lime towards the top of LPAZ BH1C-1 to clarify its age and the that of determination 3450-3270 cal BP. In addition to the specific reasons provided, these determinations will allow better comparison with neighbouring records. It is also recommended that the results from this study be summarised for publication.

REFERENCES

Anderson, S.T. (1973) The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region. In (Birks, H.J.B., & West, R.G.; eds) *Quaternary Plant Ecology.* Blackwell, Oxford.

Andersen, S.Th. (1970) The relative pollen productivity and pollen representation of North European trees, and correction factors for tree pollen spectra. *Danmarks Geologiske Undersogelse II,* Raekke nr **76**.

Andersen, S.Th. (1973) The differential pollen productivity of trees and its significance for the intepretation of a pollen diagram from a forested region. In (H.J.B. Birks & R.G. West, eds.) *Quaternary Plant Ecology,* 109-115. Oxford: Blackwell Scientific.

Andersen, S.Th. (1975). The Eemain freshwater deposit at Egernsund, South Jylland, and the Eemian landscape development in Denmark. *Danmarks Geologiske Undersogelse Arbog,* **1974**, 49-70.

Batchelor, C.R. (2009) *Middle Holocene environmental changes and the history of yew (Taxus baccata L.) woodland in the Lower Thames Valley*. Unpublished PhD thesis, University of London

Batchelor, C.R., Young, D.S., Green, C.P. and Austin, P. (2011) A report on the environmental archaeological assessment of boreholes collected from the London Cable Car route, London Boroughs of Newham and Greenwich (site code: CAB11). Quaternary Scientific (QUEST) Unpublished Report July 2011; Project Number 140/10.

Batchelor, C.R., Branch, N.P., Allison, E., Austin, P.A., Bishop, B., Brown, A., Elias, S.E., Green, C.P. & Young D.S. (in prep) New evidence for the Neolithic elm decline in the Lower

Thames Valley and its association with the elm bark beetle (*Scolytus scolytus* F.). In prep.

Battarbee, R.W., Jones, V.J., Flower, R.J., Cameron, N.G., Bennion, H.B., Carvalho, L. & Juggins, S. (2001) *Diatoms.* In (J.P. Smol and H.J.B. Birks eds.), *Tracking Environmental Change Using Lake Sediments Volume 3: Terrestrial, Algal, and Siliceous Indicators*, 155-202. Dordrecht: Kluwer Academic Publishers.

Baker, C.A., Moxey, P.A. & Oxford, M. (1978) Woodland continuity and change in Epping Forest. *Field studies,* **4**, 645-669.

Bradshaw, R.H.W. (1981) Modern pollen-representation factors for woods in South-East England. *Journal of Ecology,* **69**, 45-70.

Bengtsson, L. & Enell, M. (1986) Chemical Analysis. In (Berglund, B.E. ed.) *Handbook of Holocene palaeoecology and palaeohydrology,* 423-451. Chichester: John Wiley and Sons.

Bennett, K.D. (1988) Holocene pollen stratigraphy of Central East Anglia, England, and comparison of pollen zones across the British Isles, *New Phytologist,* **109(2)**, 237-257.

Branch, N.P., Green, C.P., Vaughan-Williams, A., Elias, S., Swindle, G., & Batchelor, C.R. (2005) Bellot Street, Maze Hill, London Borough of Greenwich (site code: GBL05): environmental archaeological assessment. ArchaeoScape Unpublished Report.

Branch, N.P., Batchelor, C.R., Elias, S., Green., C.P. & Swindle, G.E. (2007) *Preston Road, Poplar High Street, Poplar, London Borough of Hamlets (site code: PPP06): environmental archaeological analysis*. ArchaeoScape Unpublished Report.

Branch, N.P., Batchelor, C.R., Cameron, N.G., Coope, G.R., Densem, R., Gale, R., Green, C.P. & Williams, A.N. (in press) Holocene environmental changes in the Lower Thames Valley, London, UK: implications for our understanding of the history of Taxus (L.) woodland. *The Holocene*, in press.

Bridgland, D.R. (1995) The Quaternary sequence of the eastern Thames basin: problems of correlation. In (D.R. Bridgland, P. Allen & B.A. Haggart, eds.) *The Quaternary of the Lower reaches of the Thames*, 35-52. Durham: Quaternary Research Association.

Bronk Ramsey, C. (1995) Radiocarbon calibration and analysis of stratigraphy: the oxcal program. *Radiocarbon,* **37(2)**, 425-430.

Bronk Ramsey, C. (2001) Development of the radiocarbon program oxcal. *Radiocarbon,* **43(2a)**, 355-363.

Bronk Ramsey, C. (2007) Deposition models for chronological records. *Quaternary Science Reviews,* **27(1-2)**, 42-60.

Cappers, R.T.J., Bekker R.M. & Jans J.E.A. (2006) Digital Seed Atlas of the Netherlands. Groningen Archaeological Series 4. Barkhuis, Netherlands

Carew, T., Meddens, F., Batchelor, R., Branch, N., Elias, S., Goodburn, D., Vaughan-Williams, A., Webster, L. & Yeomans, L. (2009) human-Environmental interactions at the wetland edge in East London: trackways, platforms and Bronze Age responses to environmental change. *London and Middlesex Archaeology Society*, **6**: 1-34.3.

Chambers, F.M., Mighall, T.M. and Keen, D.H. (1996) Early Holocene pollen and Molluscan records from Enfield Lock, Middlesex, UK*. Proceedings of the Geologists Association* **107**: 1-14.

Clark, J.G.D. (1963) Neolithic bows from Somerset, England, and the prehistory of archery in north-western Europe. *Proceedings of the Prehistoric Society,* **29**, 50-98.

Clark, S.H.E. and Edwards, K. J. (2004) Elm bark beetle in Holocene peat deposits and the northwest European elm decline. *Journal of Quaternary Science,* **19(6)**, 525-528.

Coles, J.M. & Hibbert, F.A. (1968) Prehistoric roads and tracks in Somerset, England: 1. Neolithic. *Proceedings of the Prehistoric Society,* **34**, 238-258.

Coles, J.M., Heal, S.V.E. & Orme, B.J. (1978) The use and character of wood in prehistoric Britain and Ireland. *Proceedings of the Prehistoric Society,* **44**, 1-45.

Deforce, K. & Bastiaens, J. (2007) The Holocene history of *Taxus baccata* (yew) in Belgium and neighbouring regions. *Belgian Journal of Botany,* **140(2)**, 222-237.

Denys, L. (1992) *A check list of the diatoms in the Holocene deposits of the Western Belgian Coastal Plain with a survey of their apparent ecological requirements: I. Introduction,* *ecological code and complete list.* Service Geologique de Belgique. Professional Paper No. 246. pp. 41.

Devoy, R.J.N. (1979) Flandrian sea-level changes and vegetational history of the lower Thames estuary. *Philosophical Transactions of the Royal Society of London,* **B285**, 355-410.

Divers, D. (1995) *Archaeological Excavation of the former Beckton Nursery*. Newham Museum Service Unpublished Report.

Duff, A. (ed.) (2008) *Checklist of beetles of the British Isles*. Wells, Somerset: Privately printed.

Flower, R.J. (1993) Diatom preservation: experiments and observations on dissolution and breakage in modern and fossil material, *Hydrobiologia* **269/270**, 473-484.

Garbett, G.G. (1981) The elm decline: the depletion of a resource. *New Phytologist,* **88**, 573-585.

Gibbard, P.L. (1994) *Pleistocene History of the Lower Thames Valley*. Cambridge University Press, Cambridge.

Gibbard, P. (1995) Palaeogeographical evolution of the lower Thames valley. In (D.R. Bridgland, P. Allen & B.A. Haggart, eds.) *The Quaternary of the lower reaches of the Thames*, 5-34. Durham: Quaternary Research Association.

Gifford & Partners Ltd. (2001) *A13 Thames Gateway Phase III Archaeological Works: Freemasons Road Underpass Assessment Report on Detailed Excavation*. Gifford Unpublished Report.

Girling, M.A. (1988) The bark beetle Scolytus scolytus (Fabricius) and the possible role of elm disease in the early Neolithic, In (M. Jones, ed.) *Archaeology and the Flora of the British Isles*. Oxford University Committee for Archaeology, **14**, 34-38.

Girling, M.A. and Grieg, J. (1985) A first fossil record for Scolytus scolytus (F.) (elm bark beetle): its occurrence in elm decline deposits from London and implications for Neolithic elm disease. *Journal of Archaeological Science,* **12**, 347-351.

Godwin, H. (1956) *The History of British Flora*. Cambridge: Cambridge University Press.

Godwin, H. (1964) Late Weichselian conditions in southeastern Britain: organic deposits at Colney Heath, Herts. Philosophical Transactions of the Royal Society of London **B160**: 258-275.

Gowen, M. (2004) *Unique prehistoric musical instrument discovered in County Wicklow*. Available at http://www.archconlabs.com/index.php/home/58-leinster-projects/107-unique-prehistoric-musical-instrument-discovered-in-co-wicklow accessed on 11th April 2007.

Green, C.P., Batchelor, C.R. & Young, D.S. (2011) *A report on the geoarchaeological borehole investigations and deposit modelling on the London Cable Car Route, London Boroughs of Newham and Greenwich (site code: CAB11).* Quaternary Scientific (QUEST) Unpublished Report May 2011; Project Number 140/10

Hartley, B., Barber, H.G., Carter, J.R. & Sims, P.A. (1996) *An Atlas of British Diatoms.* Biopress Limited. Bristol. pp. 601.

Hather, J. G. (2000) *The Identification of the Northern European Woods: A Guide for archaeologists and conservators.* Archetype Publications Ltd, London.

Holder, N. (1998) *An Archaeological Excavation Assessment and Updated Project Design for Royal Docks Community School Site, Prince Regent Lane, Newham.* MoLAS Unpublished Report.

Hendey, N.I. (1964) An Introductory Account of the Smaller Algae of British Coastal Waters. Part V. Bacillariophyceae (Diatoms). Ministry of Agriculture Fisheries and Food, Series IV. pp. 317.

Huntley, B. & Birks, H.J.B. (1983) *An atlas of past and present pollen maps of Europe: 0-13,000 years ago*. Cambridge: Cambridge University Press.

Hustedt, F. (1953) Die Systematik der Diatomeen in ihren Beziehungen zur Geologie und Okologie nebst einer Revision des Halobien-systems. *Sv. Bot. Tidskr.*, 47: 509-519.

Hustedt, F. (1957) Die Diatomeenflora des Fluss-systems der Weser im Gebiet der Hansestadt Bremen. *Ab. naturw. Ver. Bremen* 34, 181-440.

Jarrett, C. (1996) *Archaeological evaluation at the East Beckton District Centre*. Newham Museum Service Unpublished Report.

Juggins. S. (2003) C2 User guide. Software for ecological and palaeoecological data analysis and visualisation. University of Newcastle, Newcastle upon Tyne, UK. 69pp.

Kenward, H. K. Hall, A. R. and Jones, A. K. G. (1986) Environmental evidence from a Roman well and Anglian pits in the legionary fortress. *Archaeology of York* 14 (5), 241-288. London: Council for British Archaeology.

Krammer, K. & Lange-Bertalot, H. (1986-1991) *Bacillariophyceae.* Gustav Fisher Verlag, Stuttgart.

Kloet, G. A. and Hincks, W. D. (1964-77) *A checklist of British insects*, 2nd edn. London: Royal Entomological Society.

Lakin, D. (1998) *Atlas Wharf, Westferry Road, Isle of Dogs*. MoLAS unpublished report.

McLean. G. (1993) *An outline report on an archaeological evaluation at the land at the rear of 72-88 Bellot Street Greenwich London SE10*. SELAU Unpublished Report.

Meddens, F.M. & Beasley, M. (1990) Wetland use in Rainham, Essex. *London Archaeologist,* **6**, 9.

Mitchell, F.J.G. (1988) The vegetational history of the Killarney oakwoods, SW Ireland: Evidence from fine spatial resolution pollen analysis. *Journal of Ecology,* **76**, 415-436.

Mitchell, F.J.G. (1990) The history and vegetation dynamics of a yew wood (*Taxus baccata* L.) in S.W. Ireland. *New Phytologist,* **115**, 573-577.

Moe, D. & Rackham, O. (1992) Pollarding and a possible explanation of the Neolithic elmfall. *Vegetation History and Archaeobotany,* **1**, 63-68.

Moore, P.D., Webb, J.A. & Collinson, M.E. (1991) *Pollen Analysis*. Oxford: Blackwell Scientific.

Morley, M. (2003) *Greenwich Industrial Estate, Bugsby's Way, Charlton, London SE7, a Geoarchaeological Investigation*. MoLAS Unpublished Report.

Parker, A.G., Goudie, A.S., Anderson, D.E., Robinson, M.A. & Bonsall, C. (2002) A review of the mid-Holocene elm decline in the British Isles. *Progress in Physical Geography,* **26(1)**, 1-45.

Peglar, S.M. & Birks, H.J.B. (1993) The mid-Holocene Ulmus fall at Diss Mere, south-east England – disease and human impact? *Vegetation history and Archaeobotany,* **2**, 61-68.

Pepys, S. (1665). *Samuel Pepys Diary September 1665*. Available at http://www.pepysinfo/1665/ 1665sep.html accessed on 20th April 2007.

Perry, I. & Moore, P.D. (1987) Dutch elm disease as an analogue of Neolithic elm decline. *Nature,* **326**, 72-73.

Philp, B. (1993) *An Outline Report on an Archaeological Evaluation Excavation at the Land at the Rear of 72-88 Bellot Street, Greenwich, London SE10*. SELAU Unpublished Report.

Rasmussen, P. (1989a) Leaf-foddering of livestock in the Neolithic: archaeobotanical evidence from Weier, Switzerland. *Journal of Danish Archaeology,* **8**, 51-71.

Rasmussen, P. (1989b) Leaf foddering in the earliest Neolithic agriculture. *Acta Archaeologica,* **60**, 71-86

Rasmussen, P. and Christensen, K. (1997) *The mid-Holocene Ulmus decline: A new way to evaluate the pathogen hypothesis*. Available at http://www.geus.dk/departments/environ-hist-climate/posters/rasumussen97-dk.htm accessed on 31st June 2007.

Reid, C. (1916) The plants of the Late glacial deposits of the Lea Valley. *Quarterly Journal of the Geological Society of London* **71**: 155.

Reille, M. (1992) *Pollen et spores D'Europe et D'Afrique du Nord*. Laboratoire de Botanique historique et Palynologie, Marsaille.

Reimer, P.J., Baille, M.G.L., Bard, E., Bayliss, A., Beck, J.W., Bertrand, Blackwell, P.G., Buck, C.E., Burr, G.S., Cutler, K.B., Damon, P.E., Edwards, R.L., Fairbanks, R.G., Friedrich, M., Guilderson, T.P., Hogg, A.G., Hughen, K.A., Kromer, B., McCormac, G., Manning, S., Bronk Ramsey, C., Reimer, R.W., Remmele, S., Southon, J.R., Stuiver, M., Talamo, S., Taylor, F.W., van der Plicht, J. and Weyhenmeyer, C.E. (2004) IntCal04 terrestrial radiocarbon age calibration, 0-26 cal kyr BP, *Radiocarbon* **46 (3),** 1029-1058.

Ryves, D.B., Juggins, S., Fritz, S.C. and Battarbee, R.W. (2001) Experimental diatom dissolution and the quantification of microfossil preservation in sediments, *Palaeogeography, Palaeoclimatology, Palaeoecology* **172**, 99-113.

Scaife, R.G. (1988) The elm decline in the pollen record of South-east England and its relationship to early agriculture. In (M. Jones, ed.) *Archaeology and the flora of the British Isles*, 21-33. Oxford University Committee for Archaeology.

Scaife, R.G. (2001) *East Ham FC, Pennyroyal Avenue, Beckton, London E6, an Environmental Assessment*. Unpublished HAT Report 903.

Schoch, W., Heller, I., Schweingruber, F. H., & Kienast, F. (2004). *Wood anatomy of central European Species.* Available at http://www.woodanatomy.ch accessed on 31st January 2007.

Seel, S.P.S. (2001) *Late Prehistoric woodlands and wood use on the Lower Thames floodplain.* University College, London: Unpublished PhD thesis.

Sheridan, A. (2005) Dating Scotland's past: The national museums of Scotland C14 dating programmes. *The Archaeologist,* **56**, 38-39.

Sidell, E.J. (2003) *Relative sea-level change and archaeology in the inner Thames estuary during the Holocene.* University College, London, Unpublished PhD Thesis.

Sidell, E.J., Cotton, J., Rayner, L. & Wheeler, L. (2002) *The prehistory of Southwark and Lambeth.* MoLAS Monograph 15. London.

Smith, A.G. (1981) The Neolithic. In (I.G. Simmonds & M.J. Tooley, eds.) *The environment in British prehistory*, 125-209. London: Duckworth.

Spurr, G., Scaife, R., Cameron, N. & Corcoran, J. (2001) *145-155 Albert Road, E16 London Borough of Newham: a geoarchaeological evaluation report*. MoLAS Unpublished Report.

Spurrell, F.C.J. (1889) On the Estuary of the Thames and its alluvium. *Proceedings of the Geologists' Association,* **11**, 210-230.

Stace, C. (2005) *New Flora of the British Isles*. Cambridge: Cambridge University Press.

Tamblyn, W.S. (1994) *Archaeological evaluation of Beckton areas A and B Tollgate Road, Beckton, London Borough of Newham*. Newham Museum Service Unpublished Report.

Thomas, P.A. & Polwart, A. (2003) *Taxus baccata* L. *Journal of Ecology,* **91**, 489-524.

Thomas, C. & Rackham, D.J. (1996) Bramcote Green, Bermondsey: a Bronze Age trackway and palaeoenvironmental assessment. *Proceedings of the Prehistoric Society,* **61**, 221-253.

Troels-Smith, J. (1955). Characterisation of unconsolidated sediments. *Danmarks Geologiske Undersøgelse,* Raekke IV**(3)**, 38-73.

Truckle, N. (1996) *Recent excavations on wetland sites in Beckton: A publication progress report*. Newham Museum Service Unpublished Report.

Truckle, N. & Sabel, K. (1994) Beckton Alps Ski Slope, Newham Way, East Ham E6, London Borough of Newham. Newham Museum Service Unpublished Report.

Tucker, S. (1993) *Salter Road and Rotherhithe Street, London SE16*. MoLAS: Unpublished Report.

Turner, J. (1962) The *Tilia* decline: An anthropogenic interpretation. *New Phytologist,* **61**, 328-341.

Vos, P.C. & de Wolf, H. (1988) Methodological aspects of palaeoecological diatom research in coastal areas of the Netherlands. *Geologie en Mijnbouw* **67**: 31-40.

Vos, P.C. & de Wolf, H. (1993) Diatoms as a tool for reconstructing sedimentary environments in coastal wetlands; methodological aspects. *Hydrobiologia* **269/270**: 285-296.

Waller, M.P. (1993) Flandrian vegetational history of south-eastern England. Pollen data from Pannel Bridge, East Sussex. *New Phytologist,* **124**, 345-369.

Waller, M.P. (1994a) Paludification and pollen representation: the influence of wetland size on Tilia representation in pollen diagrams. *The Holocene,* **4**, 430-434.

Waller, M.P. (1994b) *The Fenland Project, number 9: Flandrian environmental change in Fenland*. East Anglian Archaeology, Cambridgeshire County Council.

Waller, M.P. (1998) An investigation in the palynological properties of fen peat through multiple pollen profiles from south-eastern England. *Journal of Archaeological Science* **25**, 631-642.

Werff, A. Van Der & Huls, H. (1957-1974) *Diatomeenflora van Nederland*, 10 volumes

Wessex Archaeology (2000) *Fort Street (West) Silvertown, London, E16, Archaeological excavation assessment report*. Wessex Archaeology: Unpublished Report.

Witkowski, A, Lange-Bertalot, H.& Metzeltin, D. (2000) *Diatom Flora of Marine Coasts I.* Iconographia Diatomologica. Annotated Diatom Micrographs Ed. by H. Lange-Bertalot Vol. 7. A.R.G. Gantner Verlag. Koeltz Scientific Books. Königstein, Germany pp 925

Wilkinson, K.N., Scaife, R.J. & Sidell, E.J. (2000) Environmental and sea-level changes in London from 10,500 BP to the present: a case study from Silvertown. *Proceedings of the Geologists' Association,* **111**, 41-54.

Wright, E.V. & Churchill, D.M. (1965) The Boats from North Ferriby, Yorkshire, England, with a review of the origins of the sewn boats of the Bronze Age. *Proceedings of the Prehistoric Society,* **31**, 1-24.

Wright, E.V., Hedges, R.E.M., Bayliss, A. & Van de Noort, R. (2001) New AMS radiocarbon dates for the North Ferriby boats - a contribution to dating prehistoric seafaring in northwestern Europe. *Antiquity,* **75**, 726-734.

APPENDIX 1: Details of the geotechnical boreholes from the North Station (NS), North Intermediate Tower (NIT), North Tower, South Tower (ST), and South Station (SS) areas of the Cable Car, London Boroughs of Newham and Greenwich (site code: CAB11) and additional previous borehole locations

Borehole number	Easting	Northing	Depth at surface (m OD)
NS			
NSDS01	540111.26	180696.07	5.32
NSBH01A	540152.83	180702.12	4.87
NSBH01*	540152.91	180700.09	4.85
NSDS02	540167.03	180696.54	4.54
NSBH02	540135.76	180672.33	-5.52
NIT			
NITBH06	539951.44	180418.42	5.43
NITTP04	539948.69	180419.02	5.38
NITTP04A	539946.91	180419.66	5.34
NITTPH03	539969.51	180429.48	5.39
NITBH05	539980.00	180428.72	5.46
NITTP01	539973.66	180435.92	5.33
NITBH02*	539972.81	180437.25	5.28
NITBH09	539961.27	180443.27	5.18
NITBH09A	539960.26	180442.76	5.21
NITBH09B	539957.29	180440.72	5.18
NITB09	539956.00	180439.73	5.15
NITBH09D	539954.54	180439.04	5.14
NITBH09E	539948.77	180434.30	5.22
NITBH09F	539949.18	180434.77	5.22
NITBH01A	539948.55	180443.13	5.29
NITBH01	539953.33	180444.87	5.28
NITTP05	539947.94	180448.23	5.41
NITBH07	539947.14	180449.86	5.43
NITBH04	539943.82	180446.50	5.39
NITBH04X	539943.82	180446.51	5.38
NITBH08	539931.78	180444.77	5.55
NITTP8	539932.22	180442.01	5.51
NITTP07	539935.04	180437.22	5.41
NT			
NTTP03A	539864.83	180255.08	5.09
NTTP03	539861.05	180252.00	5.10
NTBH02	539850.35	180286.36	5.16
NTTP04A	539839.75	180289.65	5.15
NTTP04	539838.85	180288.11	5.12
NTDS01	539906.01	180349.48	2.66
NTDS02	539918.06	180300.72	2.72
NTBH01*	539868.52	180300.77	2.76
NTBH03**	539869.01	180300.01	2.75
ST			
STBH01	539655.23	179973.19	-8.72
STBH04	539597.20	179927.28	-3.88
STBH02	539603.46	179994.39	-5.88
STBH03	539656.99	179834.86	-4.08
SS			
SSDS04	539478.67	179745.07	5.05
SSDS03	539486.27	179791.10	5.14
SSBH03*	539507.18	179793.44	5.34
SSBH01	539527.90	179815.24	5.56
SSBH01B	539530.52	179811.84	5.64
SSBH01C**	539535.75	179817.14	5.72

SSDS02	539521.13	179780.75	5.74
SSBH02D	539513.84	179759.81	5.31
SSBH02C	539522.27	179770.42	5.50
SSBH02	539526.13	179772.51	5.54
SSBH02B	539529.00	179774.72	5.55
TU			
TUBH01	539879.91	180166.61	-4.89
TUBH02	539709.58	179986.13	-10.04

** Boreholes monitored by Quarternary Scientific in the field*
*** Retrieved geoarchaeological boreholes*

Record name	Origin	Easting	Northing
BH2	SE Gas mains	539260	179773
BH3	SE Gas mains	539359	179432
BH4	SE Gas mains	539749	179784
BH5	SE Gas mains	539525	179415
BH6	SE Gas mains	539415	179396
BH7	SE Gas mains	539499	179380
BH8	SE Gas mains	539254	179378
BH9	SE Gas mains	539313	179428
BH10	SE Gas mains	539158	179607
BH11	SE Gas mains	539204	179477
BH12	SE Gas mains	539276	179424
BH13	SE Gas mains	539277	179331
BH14	SE Gas mains	539226	179374
BH15	SE Gas mains	539317	179375
BH16	SE Gas mains	539646	178916
BH17	SE Gas mains	539716	178886
BH18	SE Gas mains	539635	178823
BH19	SE Gas mains	539694	178819
BH20	SE Gas mains	539581	179357
BH21	SE Gas mains	539470	179436
BH22	SE Gas mains	538853	179824
BH23	SE Gas mains	539581	179982
BH24	SE Gas mains	539519	180062
BH25	SE Gas mains	539476	180125
BH26	SE Gas mains	539200	180052
BH27	SE Gas mains	539205	179338
BH28	SE Gas mains	539420	180023
BH29	SE Gas mains	539002	180153
BH30	SE Gas mains	538839	180284
BH31	SE Gas mains	538941	180257
BH32	SE Gas mains	539031	180140
BH33	SE Gas mains	539042	179969
BH34	SE Gas mains	539057	179861
BH1A	SE Gas mains	539309	179742
BH2A	SE Gas mains	539339	179733
BH3A	SE Gas mains	539332	179710
BH4A	SE Gas mains	539362	179681
BH5A	SE Gas mains	539346	179663
BH6A	SE Gas mains	539389	179652
BH7A	SE Gas mains	539393	179636
BH8A	SE Gas mains	539302	179751

BH9A	SE Gas mains	539302	179738
BH10A	SE Gas mains	539321	179716
BH11A	SE Gas mains	539345	179686
BH12A	SE Gas mains	539220	179859
BH13A	SE Gas mains	539569	179881
BH14A	SE Gas mains	539741	179669
BH15A	SE Gas mains	539159	179783
BH16A	SE Gas mains	539510	179932
BH17A	SE Gas mains	539671	179750
BH18A	SE Gas mains	539436	179424
BH19A	SE Gas mains	539423	179434
BH20A	SE Gas mains	539384	179457
BH21A	SE Gas mains	539395	179474
BH22A	SE Gas mains	539499	179367
BH23A	SE Gas mains	539541	179891
BH24A	SE Gas mains	539549	179910
BH25A	SE Gas mains	539605	179838
B1.	BGS	539580	179800
B29	BGS	539611	179774
B29a	BGS	539620	179840
B29b	BGS	539670	179760
B29c	BGS	539730	179660
B29d	BGS	539180	179970
B2	BGS	539384	179634
B3	BGS	539810	179790
B4	BGS	539330	179610
B4a	BGS	539490	179910
B6	BGS	539646	179787
B7	BGS	539920	180260
B8	BGS	539900	180200
B9	BGS	539936	180402
B10	BGS	539904	180426
B11	BGS	539932	180410
B12	BGS	539946	180448
B13	BGS	539971	180463
B14	BGS	539987	180436
B14a	BGS	539850	180170
B14b	BGS	539870	180520
B14c	BGS	539910	180450
B14d	BGS	539788	180682
B16	BGS	539870	180230
B19	BGS	539946	180494
B19a	BGS	539871	180561
B21	BGS	539801	180630
B22	BGS	539990	180490
B23	BGS	539920	180450
B24	BGS	540150	180710
B25	BGS	540110	180710
B25a	BGS	540260	180740
B25b	BGS	540280	180740

APPENDIX 2: RESULTS OF THE FIELD-BASED BOREHOLE DESCRIPTIONS

Results of the field-based lithostratigraphic description of borehole NSBH01, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Depth (m BGS)	Composition
4.85 to -3.25	0 to 8.10	Made Ground
-3.25 to -4.80	8.10 to 9.65	Blue-grey silty clay (alluvium) with dark brown pockets of peat and including fragments of wood (interrupted recovery)
>-4.80	>9.65	Sands and gravels

Results of the field-based lithostratigraphic description of borehole NITBH02, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Depth (m BGS)	Composition
5.28 to -4.72	0 to 10+	Made Ground

Results of the field-based lithostratigraphic description of borehole NTBH01, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Depth (m BGS)	Composition
2.76 to 1.56	0 to 1.20	Made Ground
1.56 to -1.44	1.20 to 4.20	Blue-grey silty clay (alluvium) with occasional inclusions of waterlogged wood and Mollusca
-1.44 to -3.34	4.20 to 6.10	Dark brown; Well humified wood peat with occasional clay inclusions
-3.34 to 4.74	6.10 to *ca*. 7.50	Blue-grey silty clay (alluvium) with occasional inclusions of waterlogged wood
-4.74 to -5.84	*ca*. 7.50 to 8.60	Dark brown moderately humified peat with wood and herbaceous inclusions, becoming more sandy with depth
>-5.84	>8.60	Sands and gravels

Results of the field-based lithostratigraphic description of borehole SSBH03, London Cable Car London Boroughs of Newham and Greenwich (site code: CAB11)

Depth (m OD)	Depth (m BGS)	Composition
5.34 to 0.14	0 to 5.20	Contaminated Made Ground
0.14 to -0.86	5.20 to 6.20	Blue-grey silty clay (alluvium) with occasional inclusions of waterlogged wood and Mollusca.
-0.86 to -2.81	6.20 to 8.15	Reddish brown well humified wood peat with inclusions of silt and clay
>-2.81	>8.15	Sands and gravels